

ASTRONOMY

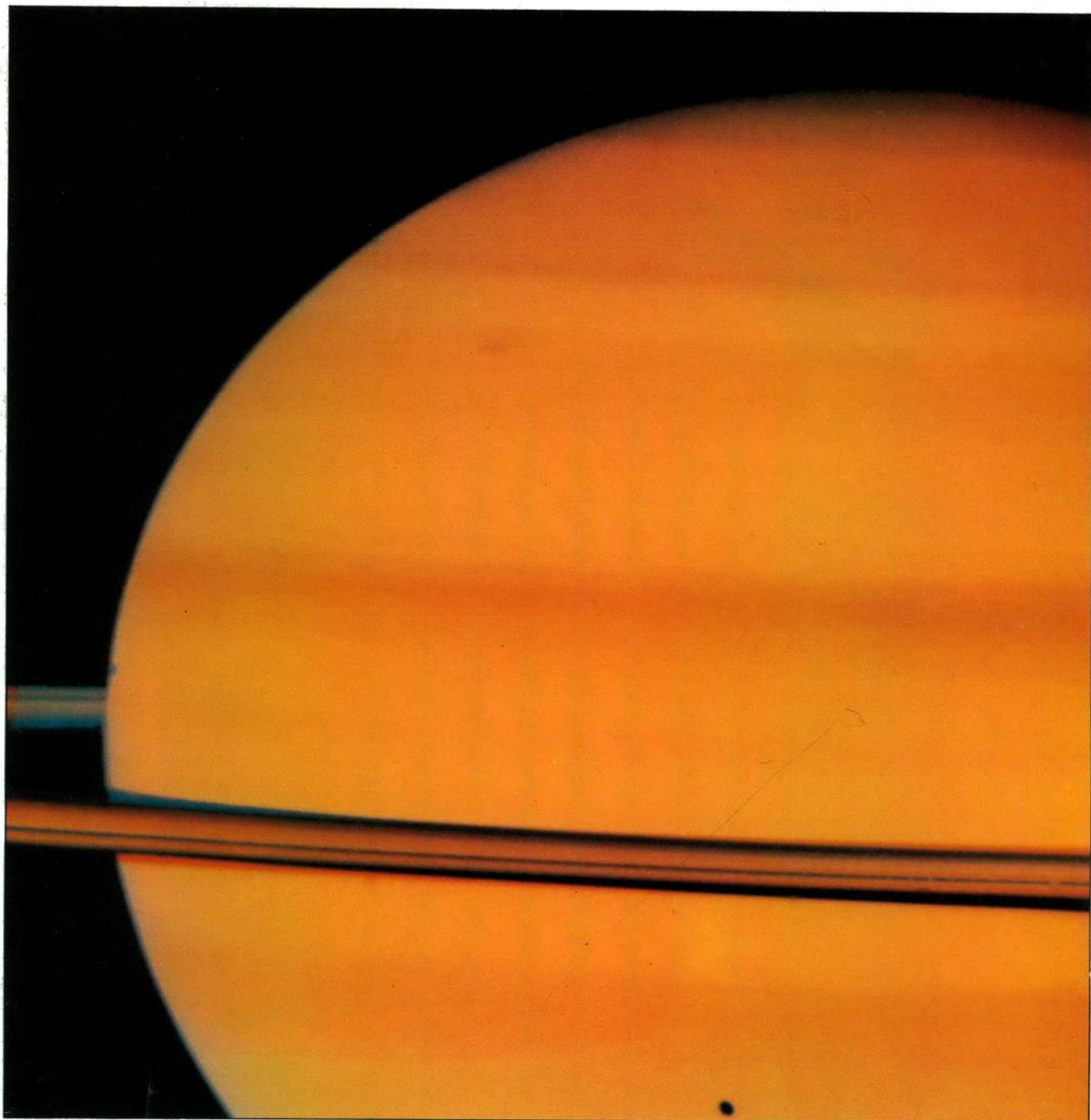
February 1981

\$2

UK 95p

Voyager: Science at Saturn

The Case of the Missing Sunspots
Observing Peculiar Galaxies



Saturn — A Space Odyssey



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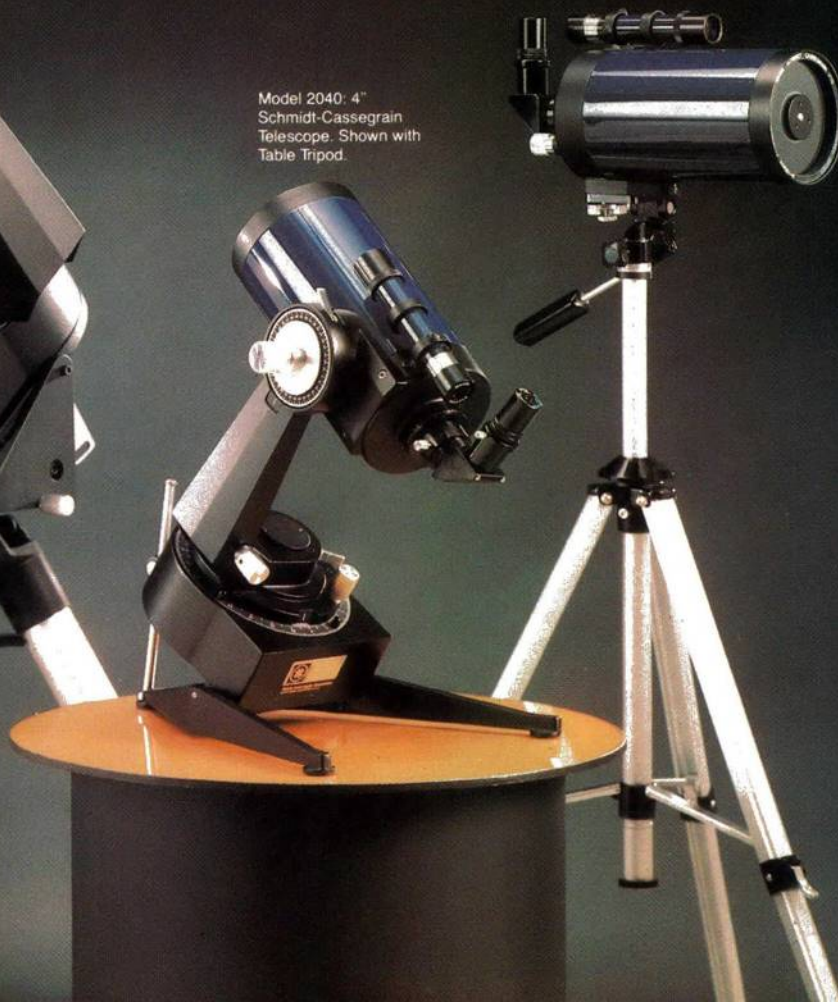
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Model 2040: 4" Schmidt-Cassegrain Telescope. Shown with Table Tripod.

4" Spotting Scope, Model 1022. Attaches to any standard camera tripod. Shown with optional Meade Photo Tripod.

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Model 2080: 8" Schmidt-Cassegrain Telescope, with Table Tripod, 4" Photo-Guide Telescope, Illuminated Reticle Eyepiece.



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PRICE LIST

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Model 1020: 1000mm f/10 Telephoto Lens	325
Model 1022: 4" Spotting Scope	395
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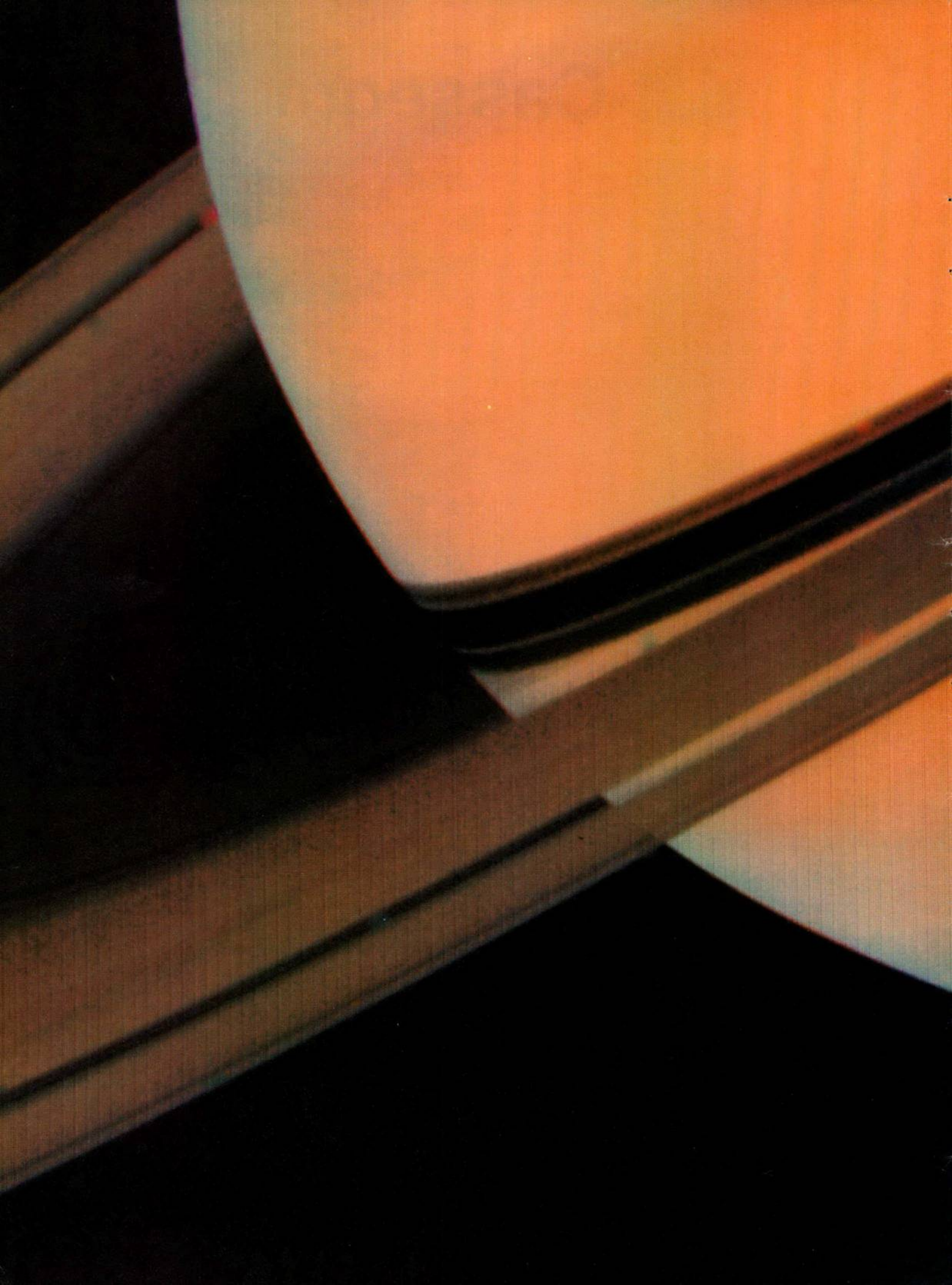
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Note: See Meade Catalog for detailed specifications and standard-accessories listings of telescope models shown.

Model 1020: 1000mm f/10 Telephoto Lens. Attaches to any standard camera tripod. Shown with optional Meade Photo Tripod.





ASTRONOMY

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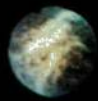
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Cover: The day before closest encounter, just before passing through the plane of Saturn's rings, the wide-angle cameras aboard Voyager 1 recorded the nearly edge-on rings, vivid yellow ball, and diffuse atmospheric features of the ringed planet. These pages: Nine days before encounter, from a range of 13 million kilometers, Voyager's "telephoto" camera captured Saturn from an angle much farther above the plane of the rings. Note the shadows of the rings on the ball of the planet and the delicate tracery of the inner C ring. JPL/NASA photographs.

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Rhea

Enceladus



Dione

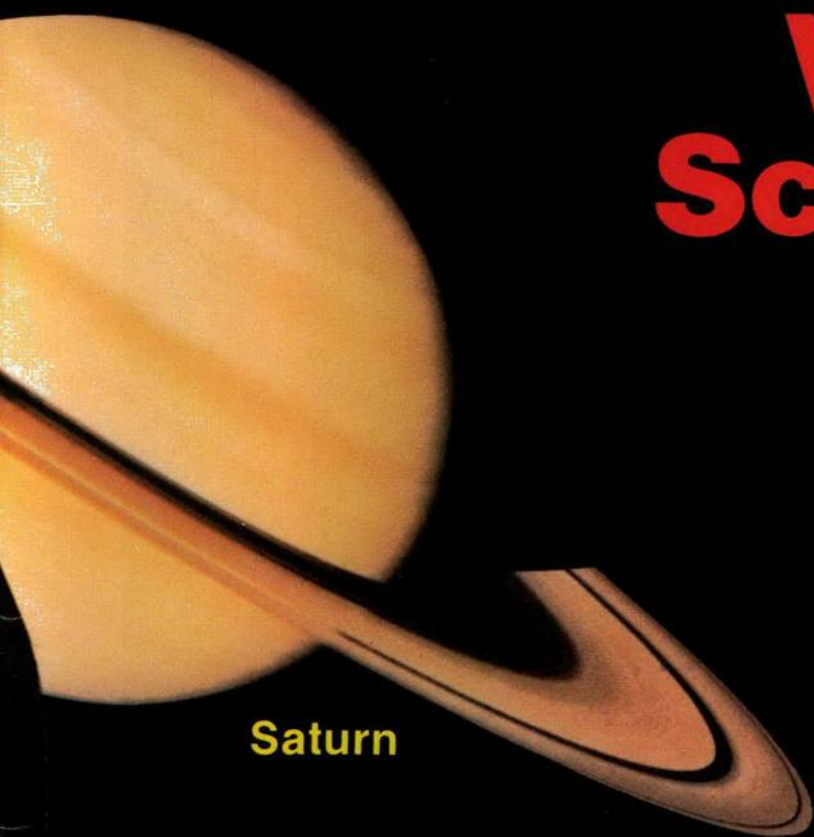




Titan

Voyager: Science at Saturn

by Richard Berry



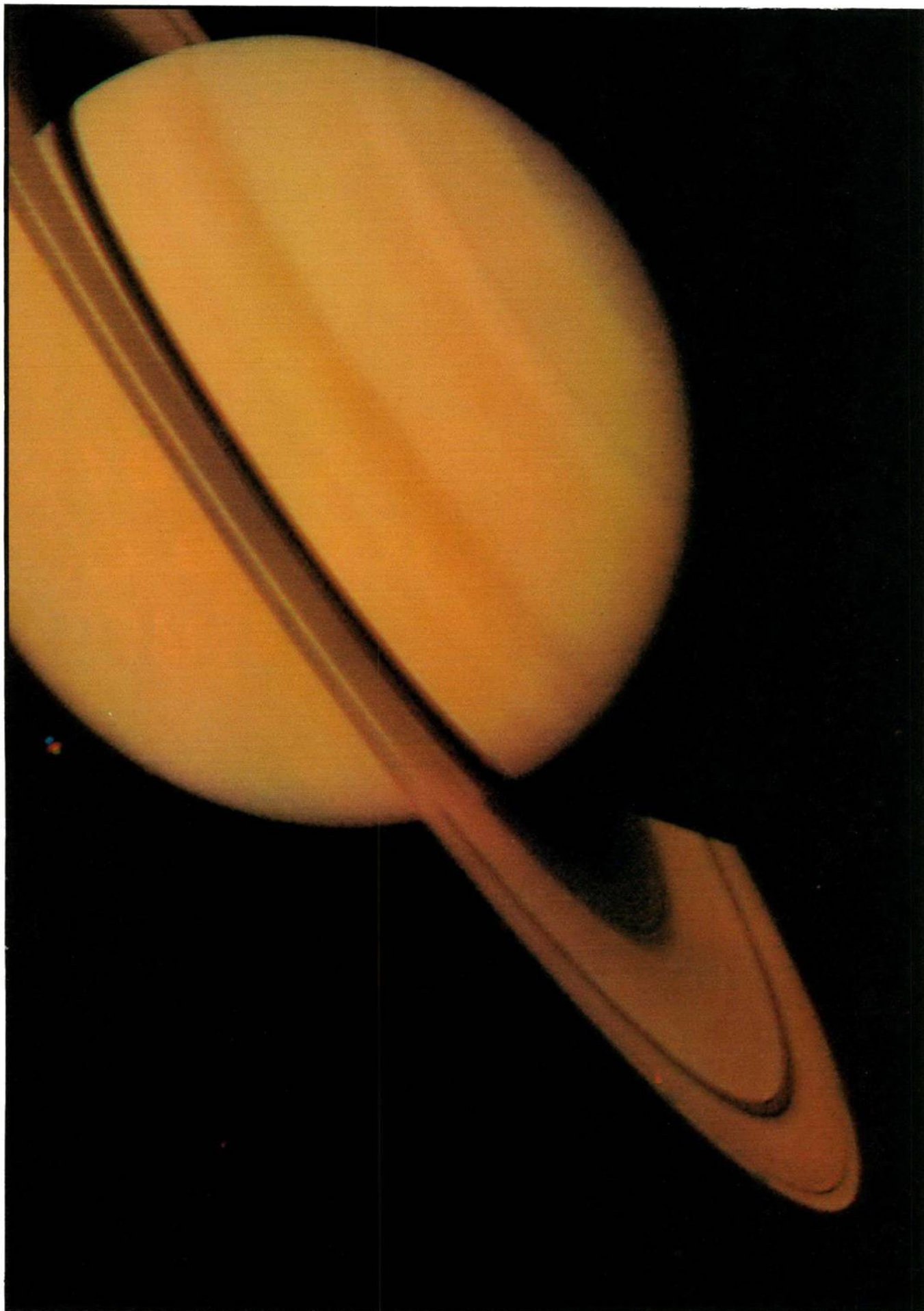
Saturn



Mimas



Tethys



SATURN

Looking back a day after flyby, Voyager recorded the night side of Saturn lit by its rings.



With the Voyager reconnaissance of Saturn, the first stage of planetary exploration is drawing to a close. There will be other explorations into the unknown — of comets, of asteroids, of the outer planets, of the magnetic and particle environment around the Sun — but never again will we explore so many new worlds.

Humans now know firsthand what every celestial body in the Copernican/Keplerian solar system looks like, know whether it possesses an atmosphere and a magnetic field, know to a first approximation the processes that have shaped its surface, and the nature of the stuff that fills its insides. There are 23 bodies in that roster — ranging from the tiny rockchunk moons of Mars to the hydrogen giant planet Jupiter that exceeds all the rest together with its mass.

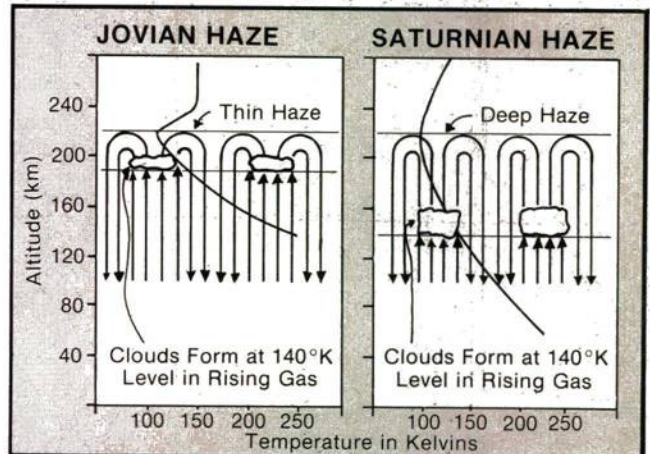
We know the cratered rocky surface of Mercury, the clouds, rock-strewn plains and volcanos of Venus, know our own Earth which we exploit for our livelihood, our Moon as a landscape of magnificent desolation and potential way station on which men have walked. We have landed robots on ruddy Mars to look for life, mapped its surface from orbit, and photographed and weighed the two carbonaceous moons, Phobos and Deimos. Jupiter we have visited four times: its changing cloud belts, its Red Spot, its new-found ring, and its harsh radiation are now familiar. We have seen craters on elongated Amalthea, watched volcanos on Io, seen the enigma of Europa's cracked face, the grooves of Ganymede, and the giant bull's eye of cratered Callisto. With the Voyager Saturn flyby, ten more bodies join the realm of the explored solar system — Saturn itself and its moons S-10, S-11, Mimas, Enceladus, Tethys, Dione, Rhea, Titan (a planet in its own right), and Iapetus.

Majestic Saturn is the sixth planet from the Sun, and second of the hydrogen giants. Its mass is 95 times that of Earth, about one-third that of Jupiter, and it has a density of 0.704 gram per cubic centimeter — less than the density of water and about half the density of Jupiter. Its equatorial radius is 60,330 kilometers, its polar radius 11% less because its 10-hour 39-minute spin flattens it. It orbits the Sun at an average distance of 9.5 times that of Earth, and therefore receives only about 1% as much light and heat from the Sun as Earth does.

The planet Saturn looks, from a distance, pale

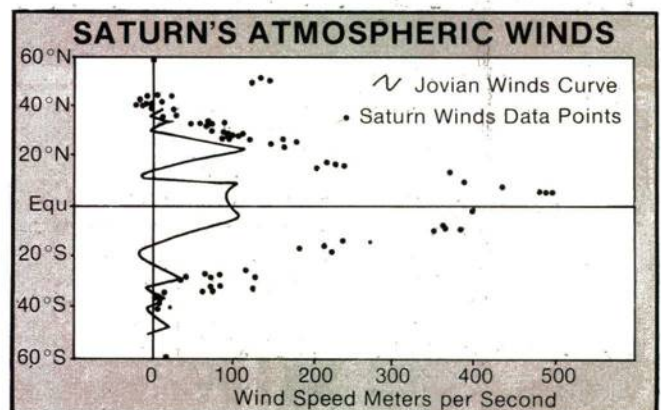
As Voyager approached Saturn and the resolution of its cameras increased, the world began to realize that the encounter would be anything but dull.

yellow with faint cloud bands. For a while Voyager scientists were worried that no detail would be seen at all. Saturn is certainly bland in comparison with Jupiter. Its clouds hide underneath an 80-km-thick aerosol haze layer that diffusely scatters back some 50% of the sunlight striking it. Both Jupiter and Saturn have such hazes, but Saturn's is much thicker because Saturn's atmosphere (at 97° K) is colder than Jupiter's (125° K). The visible clouds, composed of droplets condensed out from the warm hydrogen, methane, and ammonia gases rising from below, and colored by

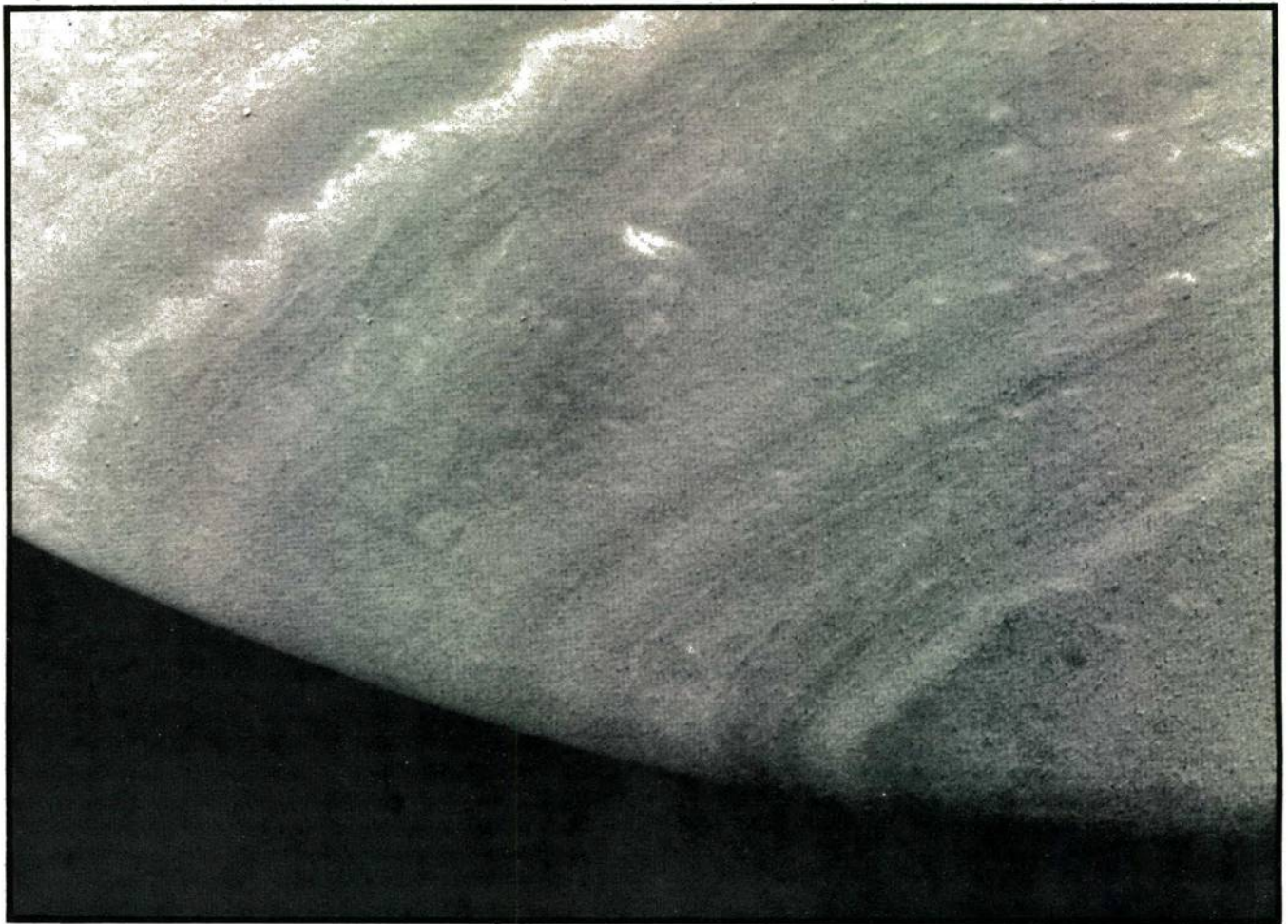


traces of hydrocarbons, sulfur, and phosphorus compounds, form deeper in Saturn's atmosphere than they do in Jupiter's. The haze itself, consisting of extremely fine particles like smog, forms in the gases above the clouds under the action of sunlight and charged particles.

Underneath the haze layer, Saturn's clouds show abundant fine structure: reddish and dark ovals with pointed ends and anticyclonic circulation, little eddies, and long "wave" features. At low latitudes, fewer and blander features embellish Saturn, but at high latitudes the cloud structure closely resembles Jupiter's. One particular orange oval, found at latitude 55° south and followed for four months, showed that Saturn, too, has long-lived oval clouds. Large-scale structure is generally absent — sheered out by the fantastic winds of Saturn.



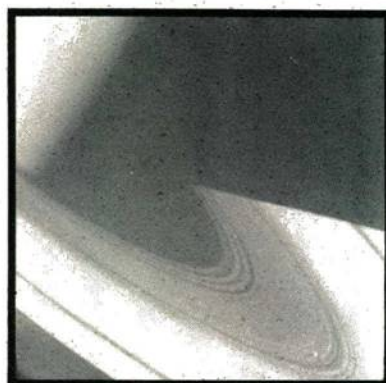
In the 300-year history of telescopic observation, less than a dozen spots were well-enough defined to measure its winds, but in a few months Voyager completely changed that. They differ from jovian winds: Saturn's equatorial winds blow eastward, in the direction of the planet's rotation, at 500 meters



The broad light and dark cloud bands of Saturn's mid-southern and south polar regions, seen at high resolution, break down into numerous small-scale waves and eddies. Note the long regular feature at the upper left, the small bright plumes, and the bland area near the pole (lower right).

per second — 1800 kilometers per hour.

What could drive such powerful winds? Saturn's winds are four times as powerful as Jupiter's and twice as wide! Saturn is colder, and its axis is tipped so that it has seasons. Saturn has half Jupiter's surface gravity at the clouds, and its core is smaller. Both planets are more efficient than Earth at converting the energy from upwelling material into zonal flow (i.e., winds). Even though the eddies drive the flow on both planets by bursting up, dissipating, and contributing their energy, some crucial difference remains.



The soft evening terminator marks Saturn as a planet with an atmosphere.

There is one intriguing candidate: both planets radiate more heat than they receive from the Sun, internal primordial heat left over from their formation and, although Saturn radiates less than

Jupiter, a larger percentage of its heat comes from inside. While Jupiter radiates 1.7 times the energy it receives from the Sun, according to Pioneer 11 data, Saturn radiates 2.8 times as much as it receives. This may account for the deep-seated differences in the winds.

The source of the jovian heat is entirely primordial — heat left over from the collapse of the proto-Jupiter to its present size. Saturn is smaller and would have generated less primordial heat. Theoreticians predicted another possible source of heat for Saturn: the separation of the helium from hydrogen as the planet cooled some 2.5 billion years ago.

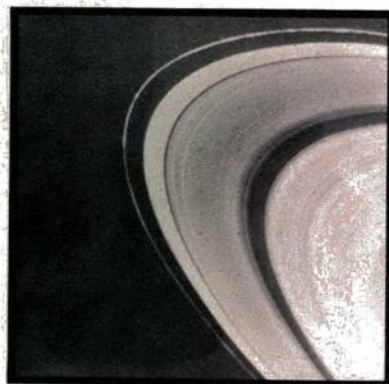
However, Voyager's instruments determined the helium to hydrogen ratio for Saturn. It turned out to be just about the same as the solar and the jovian He/H ratio, about 0.10. If the helium separated from the hydrogen, the observed He/H ratio should be lower for Saturn. Perhaps theoretical models of the behavior of hydrogen and helium at high pressure and temperature need revision, or Voyager's more sophisticated infrared instruments, once the data from them are reduced, will reveal the Pioneer 11 measurements to be in error.



Similar in size and structure to Jupiter's white ovals, this orange spot located 55° south of Saturn's equator was observed for four months by Voyager. It is about 6,000 km long.

THE RINGS

After flyby, the irregular F ring and the B ring spokes shone brightly.



The rings of Saturn are not unique, but they certainly are the largest, most intricate, and showiest in the solar system. Pioneer 11 placed an upper limit on their mass — about one ten-millionth the mass of Saturn — equivalent to a ball of ice 500 kilometers in diameter, but probably somewhat smaller. The rings are reddish, tan, or brownish. Their infrared spectra show strong characteristic bands of ice, but pure ice is white. Their color comes from damage in the crystalline lattice of the ice caused by prolonged exposure to energetic atomic particles and ions from the magnetosphere of Saturn.

The rings consist of billions of chunks of ice from the size of fine dust up to house-size pieces and even larger, each orbiting Saturn in its own individual orbit. Although there has been much debate in the last few decades, most scientists think that the rings date back to the formation of the solar system, and were formed either by the breakup of a moon that passed too close to Saturn or the failure of material that might have formed a moon to consolidate. In any event, at the temperatures measured by Voyager — 70° to 75° K in the B ring — chunks of ice larger than a baseball are stable over the age of the solar system.

Classically, the rings have been divided into three main zones: the A ring, the B ring, and the C, or "Crepe," ring. Voyager showed that each is subdivided into hundreds of narrow ringlets right down to the limit of resolution of the Voyager cameras — a few kilometers. So much fine structure was unexpected: only a relatively small number of gravitational resonances with the satellites "should" have been present.

At present, hundreds of narrow ringlets are unaccounted for. Astronomers have little doubt that gravity, for the most part, controls the rings. There's nothing wrong with physics — but solutions to equations involving billions of bodies undergoing frequent collisions are extremely complex.

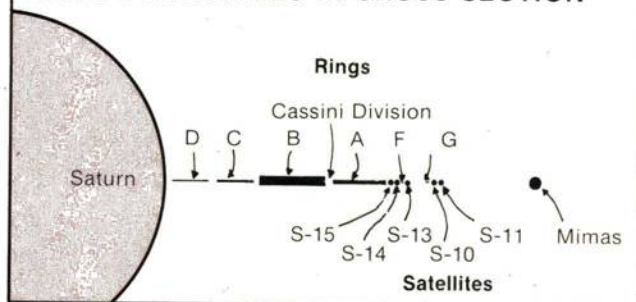
One of the most important questions is the size of the chunks that make up the rings. Voyager conducted several experiments aimed at answering that question, all based on the interaction between the ring chunks and light.

First, Voyager cameras viewed the rings from a wide range of angles relative to the Sun — from the front (sunlit) side, through the rings, and from behind. Large icy chunks are brightest from the front; viewed from behind they are dark because their backsides are in shadow. Minute icy particles as small as the wavelength of light, such as the solids in cigarette smoke, are dim from the front but look bright from behind because they scatter light forward rather than back toward the source of illumination.

Second, Voyager transmitted radio at two wavelengths through the rings. Using techniques similar to the optical transmission and scattering methods, another range of sizes was investigated.

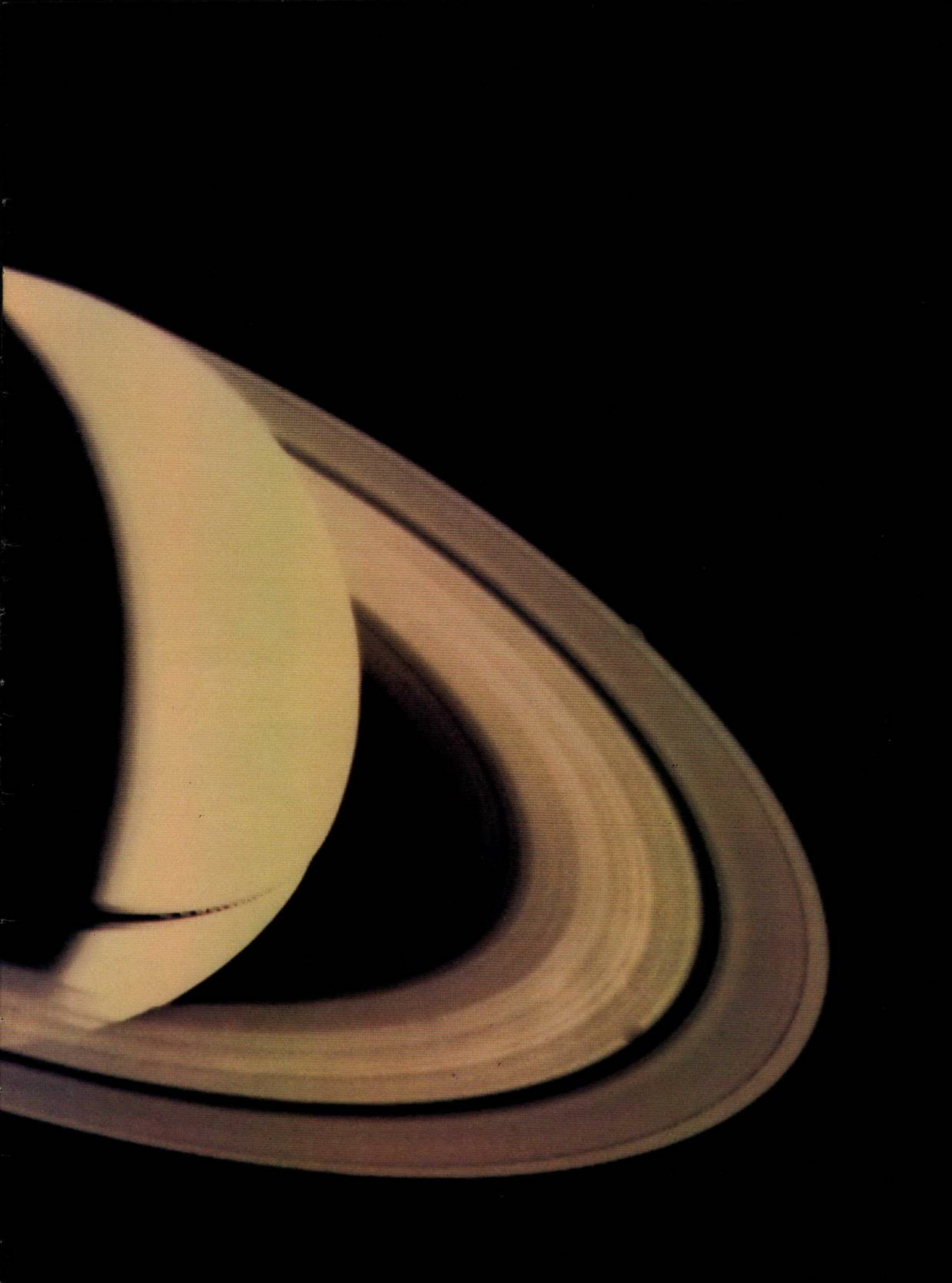
Finally, radio power was beamed down on the rings, illuminating them, and the scattered energy measured at Earth, in an experiment sensitive to chunks about the size of the radio wavelengths used.

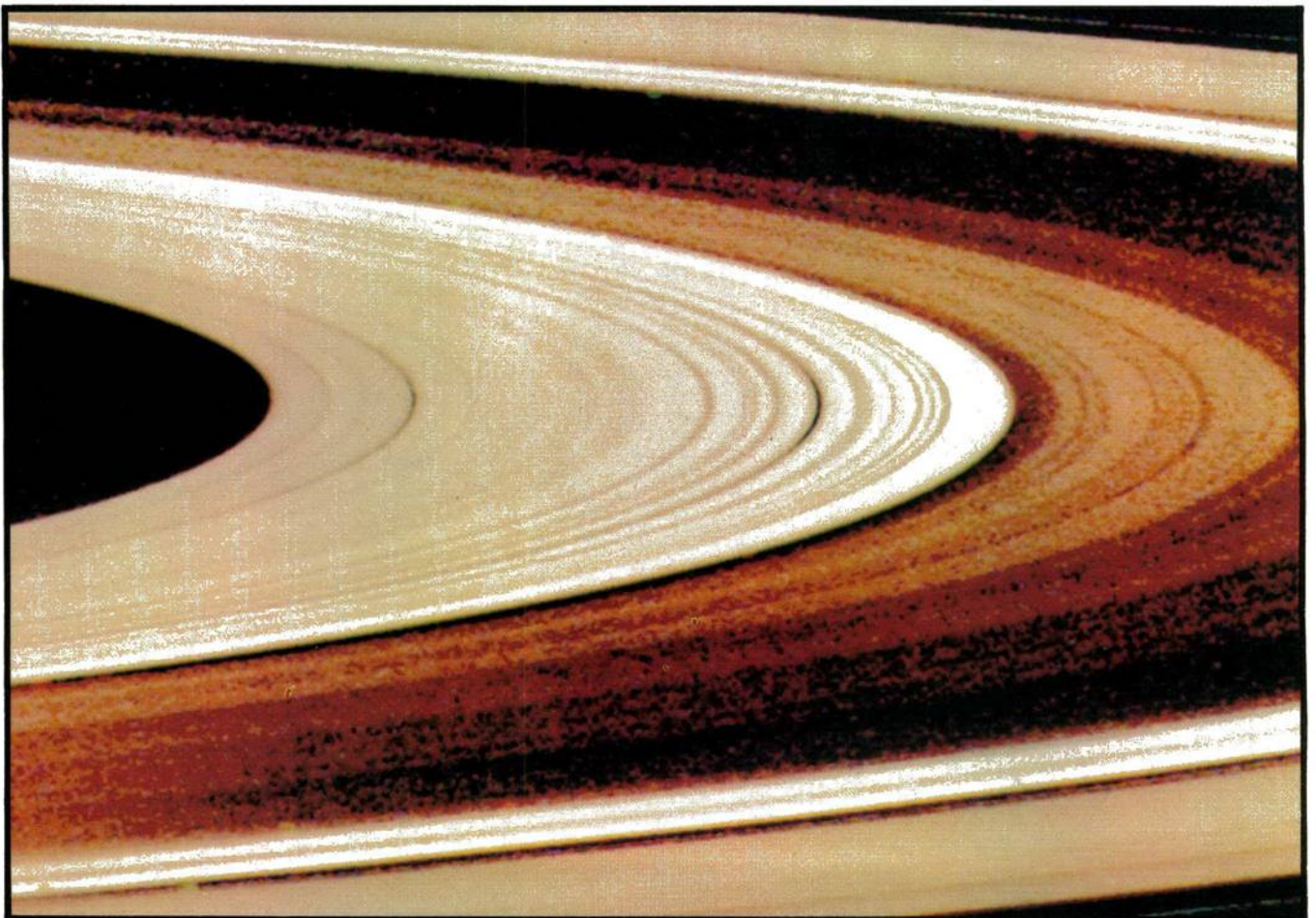
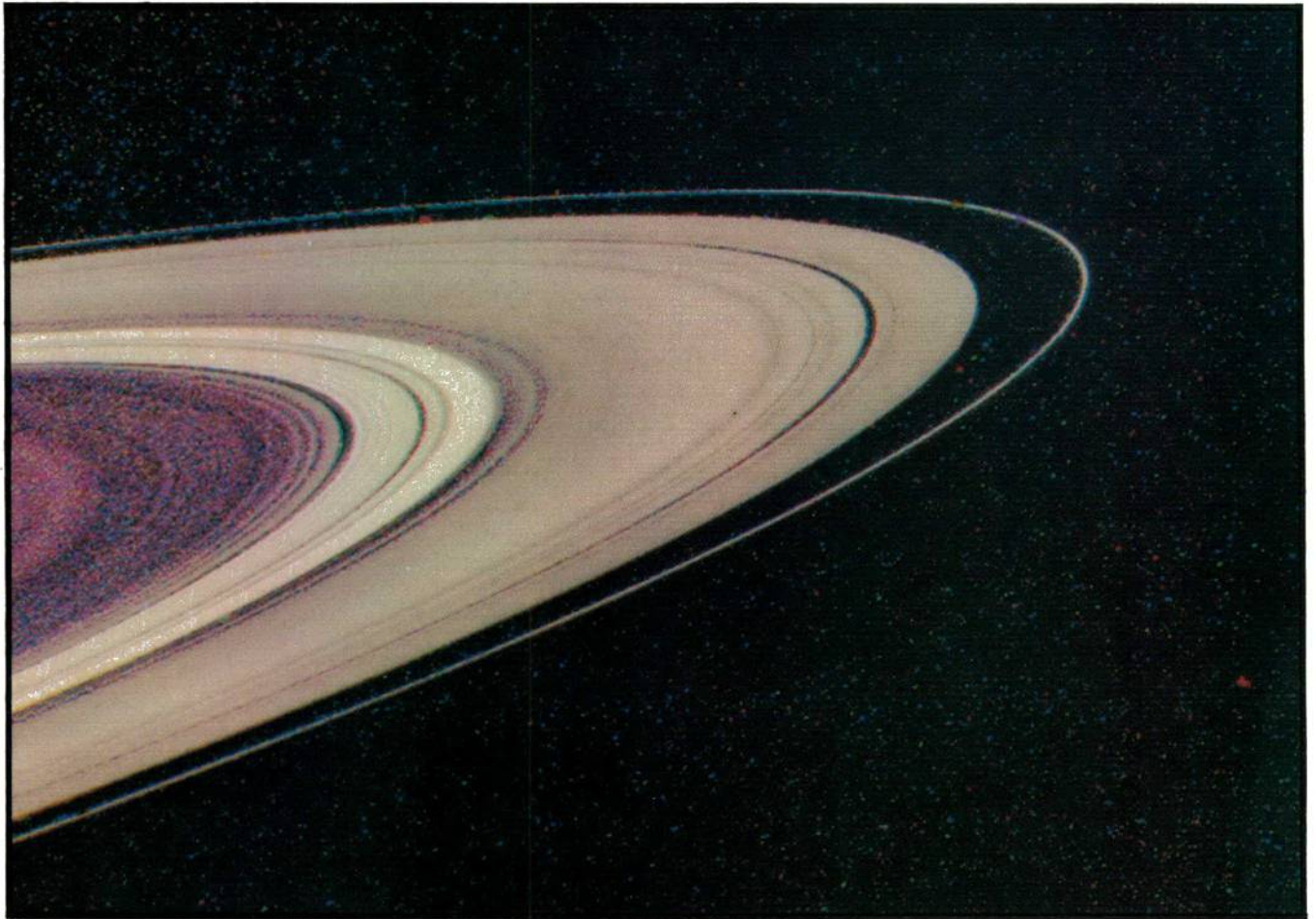
RINGS & SATELLITES IN CROSS SECTION



Overleaf photo: Four days after encounter, Voyager transmitted this backlit image of Saturn from a perspective never before seen by humans. Saturn's shadow falls across the rings.







While the most likely cause of the multiplicity of thin rings is small satellites, hundreds of them 50 kilometers in diameter could easily go undetected on Voyager images because they would tend to blend into the ring. The satellites would act to "herd" nearby smaller bodies into narrow ringlets.

The innermost of the rings that we now know orbit Saturn is the D ring. The D ring extends from the surface of Saturn out to the inner edge of the C ring. Its existence was suspected, based on Earth-based photographs, but it could never be confirmed. Voyager saw no sign of it at all during the approach, but long-exposure photographs detected it in forward scattering. The material in it is probably fine particles, coming from the C ring, "leaking" past a



At high resolution, the Cassini Division revealed complex structure. Parts of this region are made of 10-meter chunks of ice.

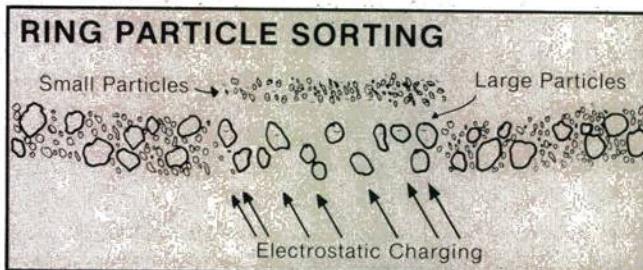
hypothetical satellite resonance that defines the inner edge of the C ring. D ring material, because of drag forces on it, must spiral rapidly into Saturn's atmosphere.

The C ring is the innermost of the classical rings. From Earth, and from the Voyager spacecraft on approach, it is dim — reflecting back a few percent of the light that strikes it. The shadow that it casts on Saturn is not dark. But, from the underside of the ring plane, it is brighter than either the A ring or B ring. The radio occultation data show that a typical particle in the C ring has a diameter of one meter, and those bodies are spaced about 20 meters apart on the average. The gaps in the C ring are somewhat regularly spaced. The C ring contains a narrow ringlet that is slightly eccentric and not equally bright all the way around.

The B ring is the broadest, brightest, and most opaque of the rings from the sunlit side. It is separated from the C ring by a broad gap on the inside and from the A ring, at the outer edge, by the Cassini Division. The B ring displays an astonishingly large number — many hundreds — of fine bright and dark ringlets distributed without any apparent regularity. They range in width down to the limit of the Voyager cameras' resolution. As spectacular as the huge number of "grooves" on computer-enhanced photographs are, the ringlets aren't very easy to see. Most of them vary in brightness by only 10% to 30%

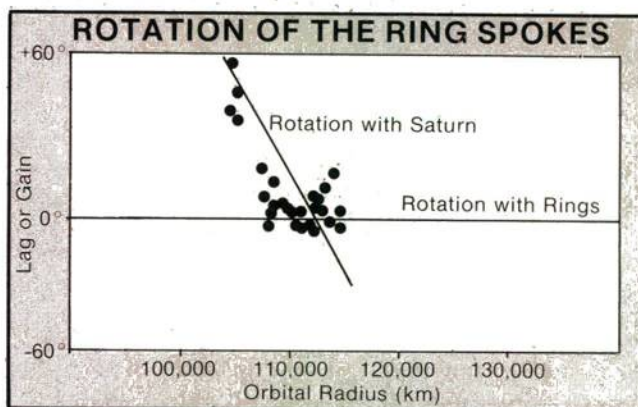
From below, Saturn's rings reveal a different aspect. Top: The Cassini Division, normally dark, is the bright band; around it arcs the A ring. The narrow F ring is outermost. Bottom: Both the Crepe ring and the Cassini Division shine bright, while the nearly opaque B ring is dark reddish-brown.

from the average brightness of the ring. As Voyager flew beneath the ring plane and looked onto the shadowed side, the B ring became dark, with a few thin bright rings shining through, implying that the B ring is rather opaque to light. However, as Voyager left Saturn, and viewed the ring from a high angle, some parts of the B ring allowed the brilliant crescent of Saturn to shine through.



On approach, the B ring showed a mysterious pattern of radial spokes on the eastern ansa. The spokes moved around the ring in the direction of its rotation. They appeared 5 to 10% darker than the surface of the ring and appeared to cross both light and dark ringlets. Although they weren't visible from below the ring plane, they reappeared as bright spokes from the far side of Saturn. At first, the spokes seemed very mysterious.

Since they occur at the distance from Saturn at which ring particles and Saturn's magnetic field rotate at the same speed, Voyager scientists soon began to suspect a connection. However, it took days before a specially written computer image analysis program showed that the spokes actually do rotate with the magnetic field and not with the ring particles. The spokes are probably composed of electrically charged fine particles "levitated" out of the ring plane by Saturn's magnetic field.

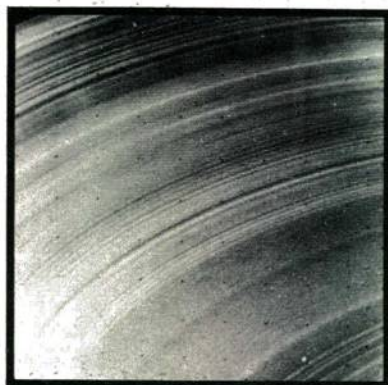


The Cassini Division is the major gap in the ring system, dividing the B ring from the A ring. Its inner edge is in resonance with Mimas, its outer edge with Iapetus. Its width is about 4000 kilometers. From the front, the Cassini Division appears about as dark as the C ring and shares a bluish tinge with it. The Division is also bright when seen from beneath the ring plane. However, it appears dark from beyond Saturn, so is thought not to have a large number of fine particles in it. The radio occultation experiment showed it contains some 10-meter chunks.

Within the Cassini Division, Voyager's cameras recorded a great deal of structure. There are four major broad bright ringlets separated by narrow gaps,

which may be “beats” between resonances, as well as one thin eccentric ring and perhaps 60 narrow dark features within the wide ringlets. The dark bands bordering the A ring and B ring are dark under all lighting conditions, so are presumably empty of material.

The A ring is much closer to what was expected for the rings: it is broad and free of large numbers of fine ringlets. It contains several narrow ringlets due to gravitational resonances as well as a wide dark resonance gap called the Encke Division. Eight hundred kilometers beyond its outer edge orbits the satellite S-15, which appears to keep the outer edge of the A ring sharp and well-defined. In backlighting, the outer edge of the A ring becomes bright, suggesting fine particles.

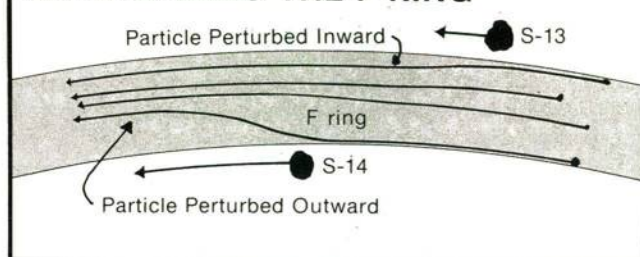


The B ring resolved into a multitude of fine rings and ringlets — some bright and some dark.

Outside the A ring orbits the narrow slightly eccentric F ring. Discovered by Pioneer 11, the F ring lies between satellites S-13 and S-14, two small bodies which confine this ring to its path. A particle escaping either inward or outward from the F ring will interact with one of these “sheepdogs” and be “herded” back into line. The F ring provides a valuable model for the multitudes of narrow rings in the main system — showing that small satellites orbiting in the rings can confine and control ring material. At moderate resolution, the Voyager cameras revealed that the F ring is not uniform in brightness all the way around, and that bright patches can be as little as 100 kilometers long. At high resolution, the F ring was resolved into three narrow “braided” strands, with kinks and twists. The bright, relatively diffuse ring is least circular. In some places it crosses over or through the other two strands. The same kinds of electrostatic and magnetic forces that deflect the spokes from strictly gravitational orbits may move fine F ring particles away from the larger chunks. This is made more likely by the fact that the F ring, the outermost dense ring, absorbs about half of the energy from energetic charged particles diffusing inward toward Saturn from the magnetosphere. In backlighting, the F ring is bright, and so is thought to contain fine particles.

Just inside the orbit of satellites S-10 and S-11 — by less than 1000 kilometers — is another narrow faint ring called the G ring. Detected because its shadow fell across S-11 in a sequence of images of the satellite, it was not seen from the sunward side and beneath the plane of the rings. It was detected faintly in forward scattering as Voyager moved away from

SHEPHERDING THE F RING



Saturn.

Extending far beyond the other rings is Saturn’s E ring, detected from Earth during the 1979-80 passage through the ring plane. It peaks in brightness at the orbit of Enceladus, and extends to eight Saturn radii from the planet. It may be a hundred kilometers thick. Enceladus is thought to be the source of the material in this ring. Voyager’s cameras detected the E ring while leaving Saturn.

Further evidence for the kinds of electrical activity in the rings invoked to explain the spokes and the braided F ring came from the planetary radio experiment, which detected short intense bursts of radio power resembling terrestrial lightning as it passed Saturn. While the source of the radio bursts might be Saturn, at the wavelengths involved, Saturn’s ionosphere cuts off radio emission, thus eliminating lightning in Saturn’s clouds as the source. The rings are an alternative source of lightning; they almost certainly possess electric fields and consist of electrically non-conductive particles undergoing frequent collisions. The rings, however, do not have a dense enough atmosphere to produce an intense flash of light. If there are lightning strokes in the rings, they are extremely powerful: the radio data show the voltages involved are about a million times greater than observed in terrestrial lightning.

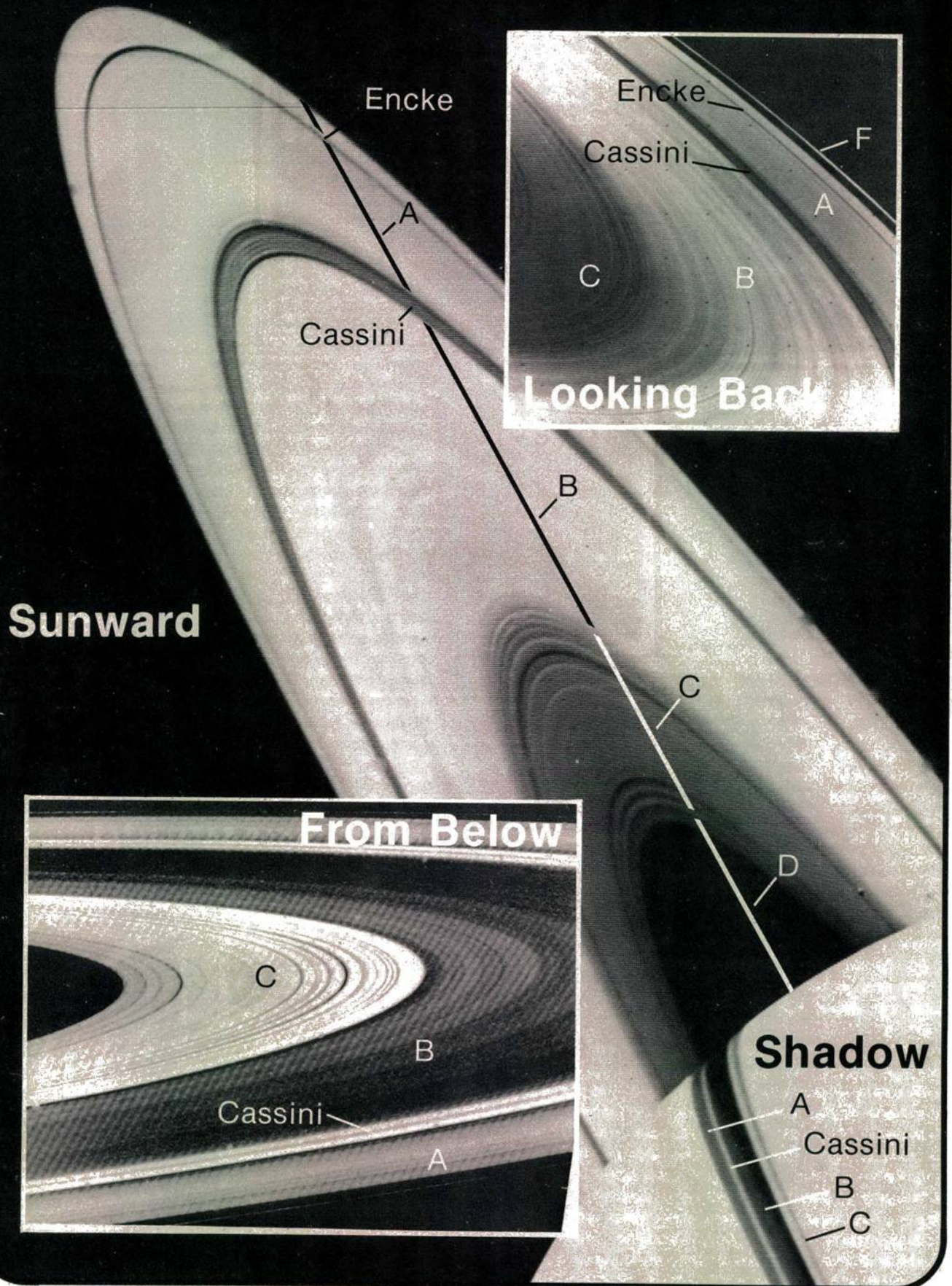
TITAN

Titan, although nearly featureless, has a dark haze hood over the northern pole.



Titan is the “Jupiter” of the Saturn system. It is not only larger and more massive than the other bodies that orbit Saturn, it’s also more interesting as a planet in its own right. Voyager’s Titan results are fascinating, revealing a world that is profoundly alien but disappointing, for we cannot see the surface of that world. It’s a world with no surface rocks, no craters, harboring a strange geology based on hydrocarbon goo, the weird properties of ammonia-modified water ice, and lakes of liquid nitrogen. For the simple

Views of Saturn's Rings



reason that we could not, and cannot, see through the impenetrable smog and opaque white liquid nitrogen clouds under the haze to Titan's surface, Titan offers little to the geologists. It makes up for this deficiency, however, with its atmosphere.

Voyager flew past Titan at a distance of 2500 kilometers, photographing first the bright side and then, as it passed into Earth and Sun occultations, probing the atmospheric composition via ultraviolet absorption of sunlight, and, with a radio signal beamed through the atmosphere toward Earth, sought the diameter of the solid body of Titan. Voyager's cameras searched for rings and satellites around Titan and found none; its magnetometers sought a Titan magnetic field and found essentially none.

As revealed by Voyager, Titan is slightly smaller than Jupiter's satellite Ganymede and slightly larger than Callisto. Its density, about 1.95, shows that it is made of about half rocky silicate materials and half ice. Voyager found no measurable magnetic field at



The northern haze hood is several hundred kilometers high in Titan's atmosphere.

Titan, an important finding because it means that Titan has no large, electrically conductive core. Titan is thus quite similar to those two jovian satellites internally — a rocky core surrounded by a thick icy mantle. Titan, however, is farther from the Sun and has been able to retain an atmosphere, something that neither of the two jovian worlds could.

To Voyager's cameras, Titan appeared to be an almost featureless orangish globe encircled, at about 200 kilometers above its visible limb, by a thin layer of haze high in its atmosphere. Over the north pole lay a slightly darker orange veil of haze, like a skullcap. The entire southern hemisphere looked slightly lighter than the northern hemisphere, perhaps a reflection of the season, for by Titan's 30-year-long calendar, the date was about April 1 — the beginning of northern "spring."

Titan's atmosphere is composed mainly of nitrogen, detected by the ultraviolet spectrometer, with a very important 1% of methane (CH_4), and traces of ethane (C_2H_6), ethylene (C_2H_4), acetylene (C_2H_2), and hydrogen cyanide (HCN). Under the action of ultraviolet light, methane molecules are broken into fragments; the hydrogen escapes from the atmosphere and the fragments recombine into the larger hydrocarbon molecules detected. Heavier hydrocarbons, such as polyacetylene, must also be made and these condense onto dust particles, filling the upper atmosphere with "smog" that obscures the

planet. Sunlight acting on hydrogen cyanide may build complex polycyanides, materials with a characteristic reddish tinge that could account for Titan's color.

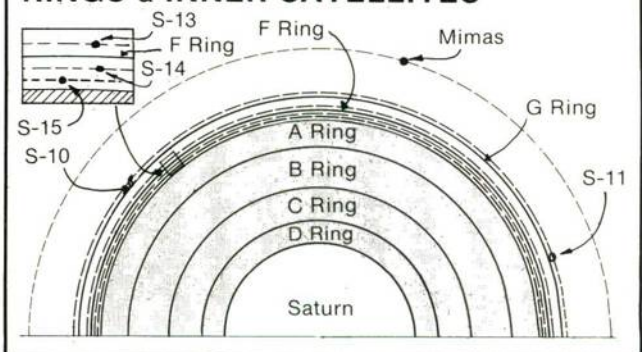
THE MOONS

Cold icy Mimas, Saturn's nearest large moon, carries a giant impact scar on one side.



Saturn is orbited by a retinue of at least 15 satellites (see the table on page 20), three discovered by Voyager during the flyby. Aside from their physical properties, some of these satellites are unusual in another way: they do not each occupy a single orbit. S-10 and S-11, discovered in 1966 and formerly thought to be a single tiny satellite, share two nearly identical orbits that differ in radius by only 50 kilometers. The smaller satellite, about 300 km in diameter, orbits in a slightly smaller and faster path than its 400 km diameter companion, and will overtake it at the present rate of approach in January 1982. Exactly what will happen is of great interest to celestial mechanics, for according to classical orbital mechanics, they can pass. How? As they approach each other, they perturb each other into increasingly eccentric orbits until, at closest approach, with one at peri-saturn and the other at apo-saturn, they pass. What surprises the scientists is not the math, which has been known for a hundred years, but finding a textbook case in nature.

RINGS & INNER SATELLITES



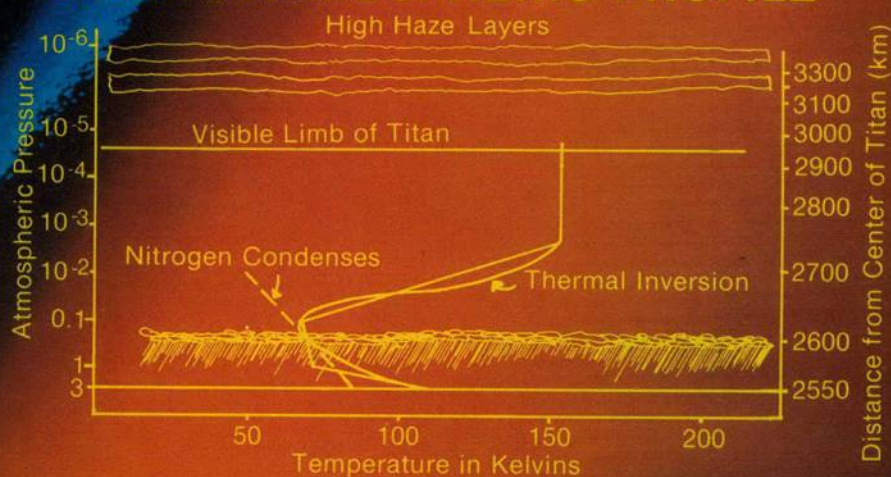
The two satellites that stand guard over the F ring are another unusual pair. Separated by only 2500 kilometers, they corral a narrow eccentric ring between them, and every several months, the inner satellite passes by the outer satellite. A gravitational resonance with Mimas may have kept them stable in this unlikely configuration.

Finally, there is Dione B. Also known as S-12, it

Titan Data

Diameter	5118 kilometers
Mass	1.36×10^{26} grams
Density	1.95 gm/cm^3 (approximately)
Composition	Rocky core, thick icy mantle
Rank in Size	Smaller than Ganymede (5270km), larger than Callisto (4840km)
Atmosphere	99% Nitrogen, 1% Methane, plus ethane, ethylene, acetylene, 3 ppm hydrogen cyanide
Surface Pressure	Approx. 1.5 bars (Earth atmospheres)
Surface Temp.	91°K
Origin of Atmos.	By outgassing from planet
Visible Limb	200 kilometers above surface
Gross Appearance	Nearly featureless orange disk, slightly darker northern hemisphere, darker northern haze cap
Surface	Possible cold hydrocarbon deposits, possible liquid nitrogen lakes
Magnetic Field	Less than 0.1% Earth's (i.e., nearly none)
Core	No large conductive core
Radio Emission	20kW of power at 50kHz
Environment	Sometimes in Saturn magnetosphere, sometimes in the solar wind

TITAN'S ATMOSPHERIC PROFILE



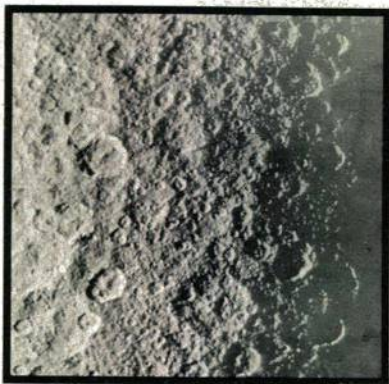
Saturn's Satellites

Name or Designation	Orbital Radius	Diameter (kms)	Density (gm/cm ³)	Albedo	Comments
S-15	138,200	200	—	—	Orbits 800km outside the A ring, limits its outer edge.
S-14	139,400	250	—	—	Orbits 800km inside F ring, removes energy from interacting ring particles.
S-13	141,700	300	—	—	Orbits 1500km outside F ring, adds energy to interacting ring particles.
S-10	151,400	200	—	40%	Leading co-orbital satellite; potato-shaped; both orbit inside G-ring.
S-11	151,450	70x135	—	40%	Trailing co-orbital satellite; has cratered surface, irregular shape, icy composition.
Mimas	185,400	390	1.2	60%	100km crater at sub-Saturn point; backside heavily cratered, has trenches; icy surface.
Enceladus	238,200	500	1.1	100%	Quite smooth; devoid of large craters with normal relief; faint linear markings; icy surface.
Tethys	294,600	1050	1.0	80%	Heavily cratered; one hemisphere darker; huge branching canyon system; large albedo feature; icy surface.
Dione	377,400	1120	1.4	60%	Large basin at the center of wispy terrain one side; unsaturated cratered plains on other side; icy surface.
S-12	377,400	80	—	—	Also called Dione B; shares orbit with Dione at the L-4 point.
Rhea	526,800	1530	1.2	60%	Two heavily cratered terrain types, bright has large craters, dark no large impacts, wispy terrain like Dione's; icy surface.
Titan	1,222,000	5118	1.9+	19%	Reddish-orange color; cold massive N ₂ atmosphere with 1% CH ₄ ; high hydrocarbon hazes.
Hyperion	1,482,000	310	—	30%	Eccentric orbit; very little visible in Voyager images.
Iapetus	3,562,000	1440	1.2	3% and 50%	Inclined orbit; leading side very dark, rear side bright; has large circular dark region.
Phoebe	12,960,000	150	—	—	Inclined, eccentric, retrograde orbit.

was discovered last year from Earth. Dione-B shares Dione's orbit, oscillating slowly around the L-4 lagrangian point and leading Dione by about 70°. Voyager attempted to photograph Dione-B, but missed it, and the trailing lagrangian point (L-5) was also searched for satellites, but none were found there.

Saturn's small icy moons are a new kind of solar system body, "mini-planets," with masses between 1% and 10% of Jupiter's large ice moons. They are cold enough to retain surface features for the age of the solar system despite being made largely of ice. Because the mass of a body determines the processes that dominate its surface, Saturn's moons provide a "laboratory" for the study of mini-planets. Jupiter's satellites are just warm enough that their craters have been altered — Saturn's satellites, with the exception of Enceladus, still carry unaltered the scars of their formation.

Iapetus has a dark leading side and a bright trailing side, as has long been known, but Iapetus' extremes exceeded expectations. The bright side, reflecting 50% of incident light, is apparently ice. The

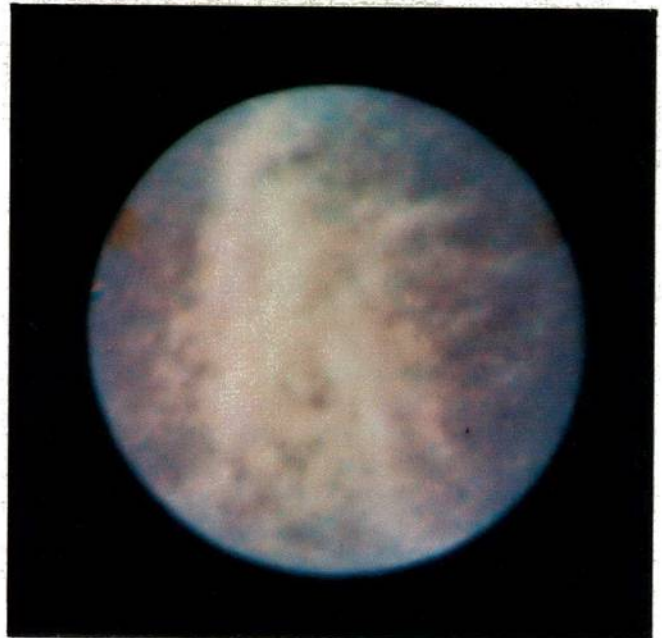


Rhea's cratered highlands have so many craters that more impacts would destroy as many craters as make new ones.

dark side, reflecting 3%, is as black as powdered coal. Voyager 1 pictures revealed a few craters and a large circular feature, possibly a crater basin, near the light and dark side boundary. It is possible that material as black as ink has flowed out of the interior and covered the dark side.

Dione's dark trailing hemisphere is crisscrossed by light-colored "wispy" markings which, at low resolution, resemble another Ganymede. At the nexus of the wispy markings is a large basin — the remnant of a giant impact feature. The wisps are associated with crustal fractures that have "leaked" the frost-deposit wisps to the surface. Dione seems to have become active internally, for although the bright areas are covered with large craters, the region opposite the basin is "processed," containing faults and graben in a smooth, lightly-cratered plain. From its density, Dione is about 30% rock.

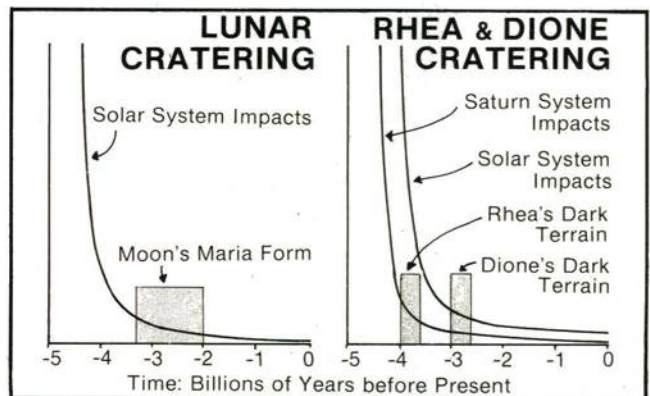
Of all Saturn's mini-planets, Voyager 1 photographed brownish Rhea in greatest detail. Rhea, like Dione, has wispy areas and regions of light-colored and darker terrain. The bright regions are cratered to saturation — new craters destroying or covering old craters with debris — as are the dark regions. However, the dark regions do not have as many large craters on them. Geologists suspect that two populations of impacting bodies built and



This image of Rhea's trailing side has been color-enhanced to show the wispy white marks on a light gray "dark terrain" background. Rhea is heavily cratered.

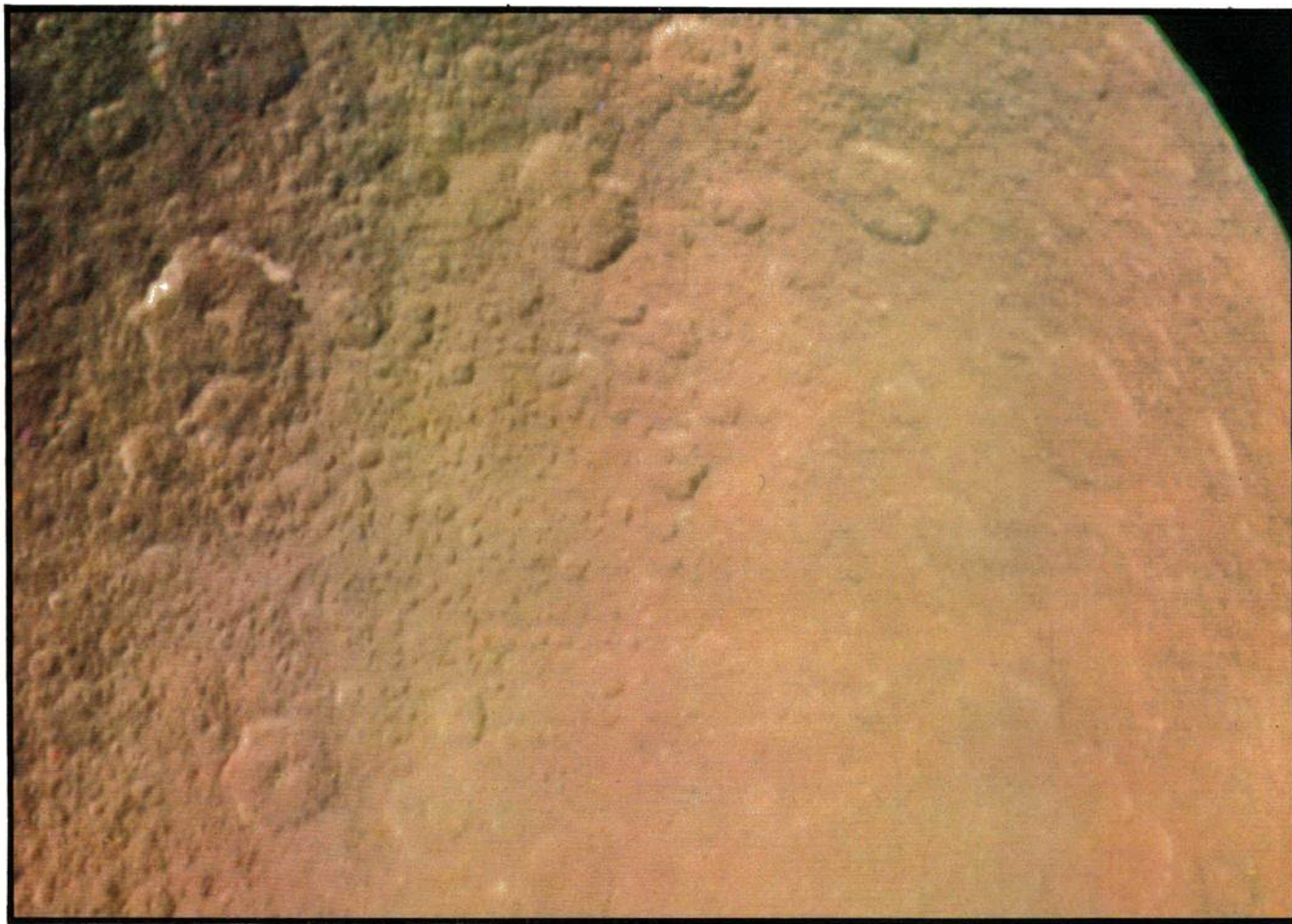
cratered Saturn's satellites. The first population, one containing large bodies, was leftover material orbiting Saturn; the second was smaller cometary bodies and other debris from the formation of the solar system. Both Dione and Rhea show evidence of two cratering episodes.

Tethys, though never recorded at high resolution, is a heavily cratered object showing a light side and dark side. Near the meeting of the terrains is a large circular feature that looks, from its shading, like an immense mountain or hill. However, since it casts no shadow at the terminator, Voyager geologists surmise that it is a modified impact basin. Opposite it



is a giant branching trench at least a kilometer deep and several hundred kilometers long. Tethys appears to have undergone little evolution, and, from its density, appears to be about 15% rock and 85% ice.

Mimas, a cold undifferentiated icy body, bears a crater-scar 100 km across with a 9 km central peak on its Saturn-facing side. This is nearly as large as it could have been without breaking the 400 km moon apart! The opposite side of Mimas, heavily cratered, has a



series of huge trenches.

Enceladus is different: Although not observed by Voyager 1 with sufficient resolution to say with certainty, it appears to be relatively uncratered and covered with faint linear markings. Its surface is also the brightest of the satellites. The orbit of Enceladus,

Like our Moon, Rhea is cratered. This area has craters of all sizes, but other areas have no large craters. White crater walls are probably freshly-exposed clean ice.

in resonance with Dione, is eccentric, so Enceladus may be a tidally heated, Europa-like body. Although the heat input is small, it may have been enough to soften the ices of this mini-planet and eradicate the ancient craters. Enceladus' orbit lies in the brightest part of the E ring and may, if it really is internally active, contribute material to the E ring.

Hyperion, photographed from a very great distance, showed only a disk — enough to make it a “world” rather than a faint point of light.

At the very bottom end of the size scale, Voyager photographed the surfaces of both S-10 and S-11, the tiny satellites that share an orbit. S-10 the larger of the two, was recorded against the disk of Saturn looking much like a gigantic potato. S-11, smaller, showed craters on its highly irregular shape. S-10 and S-11, judging from their shared orbit and irregular shapes, might once have been a single body that is now broken apart.

Voyager 1 is now traveling into deep space. Voyager 2 will pass Saturn on August 24, 1981 and fly on to the planets Uranus and Neptune. Mission controllers estimate that Voyager 2 has a 70% chance of remaining functional at Uranus and a 30% chance of functioning at Neptune. Voyager 2 may then be the only American spacecraft exploring the solar system.

Voyager 1 Saturn Photo Data

For each picture shown on these pages, the table below gives the date and the distance from Voyager to the subject. The picture number is NASA's designation and specifies the image uniquely in their files.

Page	Date	Range (kilometers)	Picture #
Cover	Nov. 11	1,750,000	260-988
4-5	Nov. 3	13,000,000	P-23058
6-7	—	composite	P-23209
8	Oct. 18	34,400,000	P-22993
10	Nov. 12	442,000	P-23211
11	Nov. 6	8,500,000	P-23067
12-13	Nov. 16	5,300,000	P-23254
14 upper	Nov. 12	717,000	P-23207
14 lower	Nov. 12	740,000	P-23111
17	Oct. 30	18,000,000	P-23074
19	Nov. 12	22,000	P-23107
21	Nov. 11	1,700,000	P-23093
22	Nov. 12	128,000	P-23208

All large color and black and white photographs in this article are courtesy of JPL and NASA; small black and white images were photographed from television monitors in the pressroom at JPL.



One thing leads to another here at Questar

Our original work in revolutionizing the astronomical telescope has certainly led us into some mixed company and into some remarkable digressions over the years. We have discovered astronomers using their Questars for bird watching in the daytime, and bird watchers turning their Questars on the moon at night—a reverse curiosity that is natural when you own a telescope that should never be idle. A Questar® can bring new compatibility to a sky watcher-bird watcher relationship.

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This detailed photograph of the moon showing the crater Clavius and surrounding area was taken with the Questar 3½. A new edition of QUESTAR OBSERVATIONS, includes some other beautiful moon photographs from our files and is available for the asking.

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ASTRONOMY FORUM

Further: A Space Odyssey

It was like standing on the foredeck of the *Santa Maria*. This time, we humans traveled on electromagnetic spectral waves, and this New World is Saturn, gaseous giant where humankind will never be able to step foot; but we could and did stop our eyes and some more exotic electronic senses there, uncovering brave little icy worlds, one orange oversized moon, and hundreds upon hundreds of brilliant rings encircling the quietly glowing Saturn, god of the ancient Titans.

This was primarily a video experience for a video generation. If things were as they should be, the entire nation, even the world, could have shared minute by minute this odyssey to new lands.

By Monday evening, the pictures don't contain the entire ring system any more; we are obviously voyaging closer; the movement in is as clear as if we were standing on the deck of Columbus' ship searching the ever-nearer virgin shoreline. As the hours pass, we feel the flight of Voyager 1 as surely as astronomers can feel the Earth turn during a long night at the telescope.

Wednesday, closest approach day, the morning press briefing in the auditorium looks like an over-booked theater. Chairs for two hundred press representatives, behind them two tiers of cameras and video machines with placid-faced operators casually filming the proceedings, another hundred or more latecomers and specially invited guests standing around both sides and in back. At 10:30 promptly it begins: the scientists parade to the podium for individual slide presentations on Titan, the rings, the moons, trajectory data, status reports, and then they all take their seats behind a sort of long dinner

table, and the questions and answers flow effortlessly. Everyone is excited. This afternoon, Voyager 1, and we — looking through its many eyes — will make closest encounter with five moons and Saturn itself.

The briefing reluctantly concludes, and the building hums with magnetic enthusiasm. Everyone is smiling, confident that this mission has already succeeded and will continue to amaze and astound. Closest approach is at 3:45; around 3:30 California governor Jerry Brown



arrives with accompanying cloud of people and cameras, including some heavies suspiciously scanning the room.

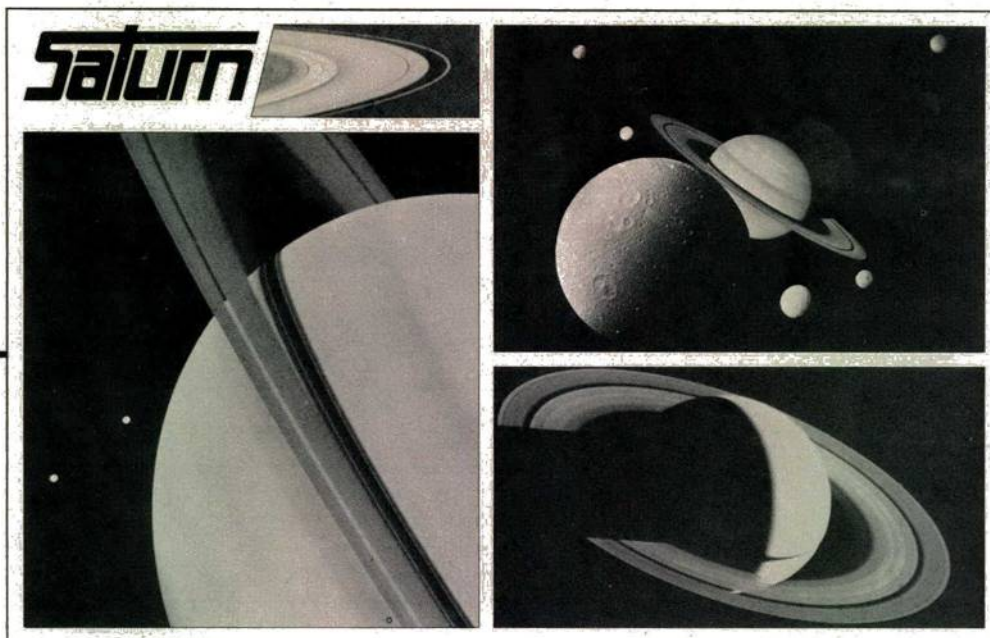
With politicians and their sycophants now causing a quiet little scene, John suggests that Stephanie go prowl around the growing crowd and pick up some predictable human interest stuff. She leaves a bit reluctantly and edges into the swarm which indicates where the Governor is. Brown is wearing his usual slit-eyed thin-haired half-worried expression and he speaks softly into microphones clutching at the air he

breathes.

Science fiction writers and dignitaries mill about. "You have to mark the occasion somehow; you can't just let it go by," remarks one quotable reporter. Two others are comparing the length of their Saturn articles; one has only 12 pages allotted while the other can ramble on for 17. Two completely disinterested cynics are discussing actuary tables on life expectancies for 70-year-old presidents-elect. Meanwhile, Al Hibbs of the Public Information Office is telling PBS-TV viewers that there are only a few minutes to go and then 3:45 comes and disappears into the unremarked past. Pictures of closest approach won't actually show up on the screens for one and a half hours; when they do, they will show an unenhanced image of Saturn as only a semicircular featureless outline. By then the celebs, hangers-on, and politicians will be gone again.

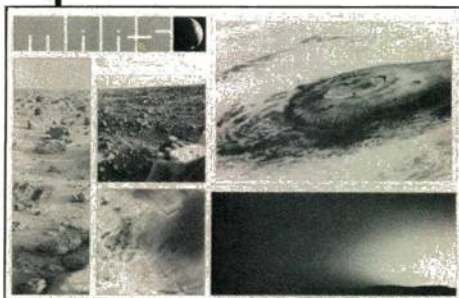
At 5:30, when telemetry has indicated closest encounter was indeed a success, that Saturn did not in fact reach up like an angry deity violated and swat the little bee buzzing by it, the formal "congratulations-we-did-it" conference starts. It's easy to snipe at the pomposities thudding like soft bricks from the raised dais, now populated by important directors and heads of branches of NASA. But the mission is, and will continue to be, a rousing success. Its discoveries are staggering in scope, in depth, and also in beauty.

President Carter, we are told, watched one of the TV programs from JPL. He called NASA to offer his congratulations. He even asked questions. Intelligent questions. Galileo and VOIR are getting White House support. What about the changing occupants of that building?...and there's no reference

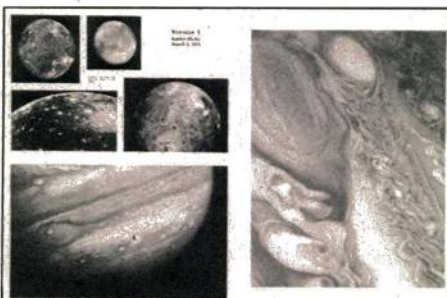


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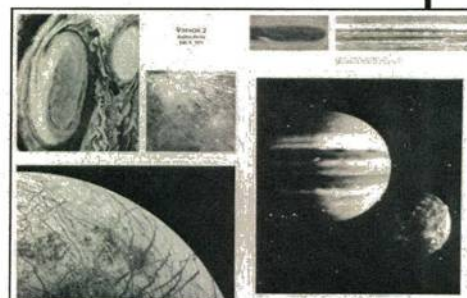
The Planets



MARS. 15 miles high by 400 wide, Olympus Mons dominates this dramatic poster, with wispy clouds, snow on the surface, rust-red rocks and extraterrestrial sunset.



JUPITER 1. Images from Voyager 1 of the Red Spot, floating satellites against the planet and close-ups of the fabulous Galilean moons.



JUPITER 2. 6 more unduplicated photos of the miniature solar system from Voyager 2. A perfect complement to the Voyager poster at left.

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to a Halley mission. What's coming next? There are no answers.

Then, as always, there's the question and answer period, itself a tribute to NASA's seemingly effortless efficiency. The entire proceedings are telecast — as always — live on a closed circuit, cameras covering both questioners and panel members, with the former handed a cordless microphone so that all can hear. Silent technicians play in an elaborate ballet of shifting cameras, mikes, and bodies, accomplished by silent semaphoric hand signals.

At this particular briefing, a TV newswoman decides it would be neat to broadcast live and loudly her own commentary from the back of the room while the briefing is in progress. The long-suffering NASA moderator tries gently several times to shush her, but she's oblivious. Finally a few well-chosen words have some slight effect. Later we hear that a complaint has been lodged by the TV station — probably under some freedom-to-be-obnoxious clause.

After the question period is over, we edge our way up to one of the bigwigs engaged in informal conversation and verify that NASA indeed is pushing hard only for the Galileo and VOIR missions, hoping no more than to "to hitch a ride with the French" for Halley's comet. We're shocked even more by that news than by his ensuing jingoistic remarks. An Irish TV journalist whom we've met is standing beside us and we exchange significant looks.

One irony of all this is that the next day, Thursday, is actually more exciting. During a period of eight hours on Wednesday, the spacecraft was almost overloaded with information from close flyby of Saturn and five of its moons, several



occultations, a couple of eclipses, and a number of attitudinal yaws, pitches, and rolls. In fact, so much data are collected (UV, IR, magnetic, radio, plasma) that transmission of

pictures is halted for six hours, being recorded onboard Voyager 1 for later playback. Now on Thursday, these riches begin to arrive. The press briefing is scheduled an hour earlier than usual. Even at that, it easily runs for two hours, stopping only because the scientists are due for TV interviews with JPL's ubiquitous Al Hibbs. Besides the PBS shows, Hibbs hosts "Saturn Watch" twice daily, an in-house telecast reviewing the latest news and on-the-spot explanations of puzzling discoveries.

Late that afternoon, five scientists talk informally in a "background briefing" in the auditorium. Only 40 or so show up to sit in a semicircle and discuss the hardcore science with them. During somewhat technical talk of weather patterns on Jupiter and the possible parallels on Saturn, we see that here the scientists are in their element. Through the technical discussions shines a glow on the scientists' faces like kids under a lighted tree on Christmas morning.

Throughout JPL, information has been streaming in; one area gets infrared, another ultraviolet, a third plasma waves, a fourth images, others radio waves. Men and women are running ecstatically between rooms, sharing the latest startling development, matching this up with that, pieces fall into some preliminary order, and here they are

sharing the puzzle with us. It's as though Columbus and his crew had a background briefing sitting on the beaches of this continent in 1492. Maybe all the questions can't be answered right away.

It's been an intense experience, and so long in coming. One scientist confides he's been working for this moment for 10 years! And the payoff is jammed into a few days, even mere hours. Like driving straight for eight hours to see a one-minute rocket firing. Like traveling 2500 miles to see a two-minute total



eclipse of the Sun. A decade of waiting and one eight-hour climax.

And now Voyager 1, her magnificent task accomplished, has begun the long lonely trek out of the solar system which made her with such loving care.

Sara Moran and J. O. Molloy
San Diego, CA

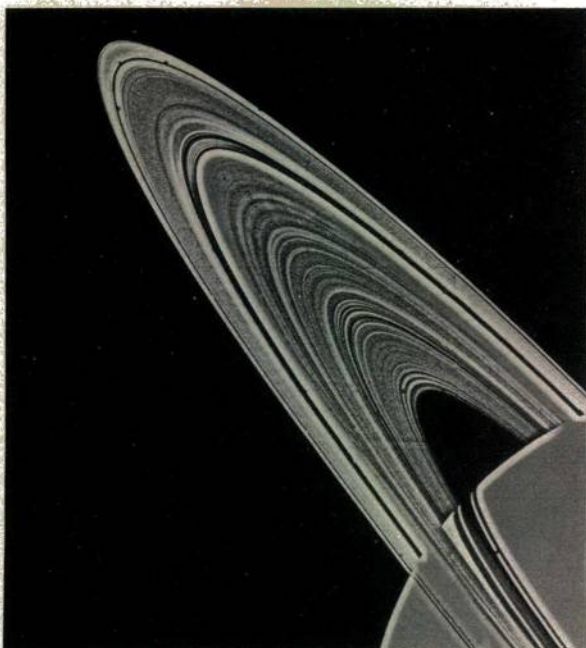
Saturnalia — "Gee Whiz"

"One billion, five hundred twenty-four million, six hundred and fifty thousand kilometers from planet Earth and closing fast on Saturn." That was the status of Voyager 1 as it neared Titan, the largest of the moons of Saturn. Stunning! — especially when contemplated as light-time. Between the transmission of "signals" by the distant space probe and their receipt at one of the three football-field sized antenna dishes around our own planet (for relay to Pasadena), one hour, twenty-four minutes, and fifty seconds would pass.

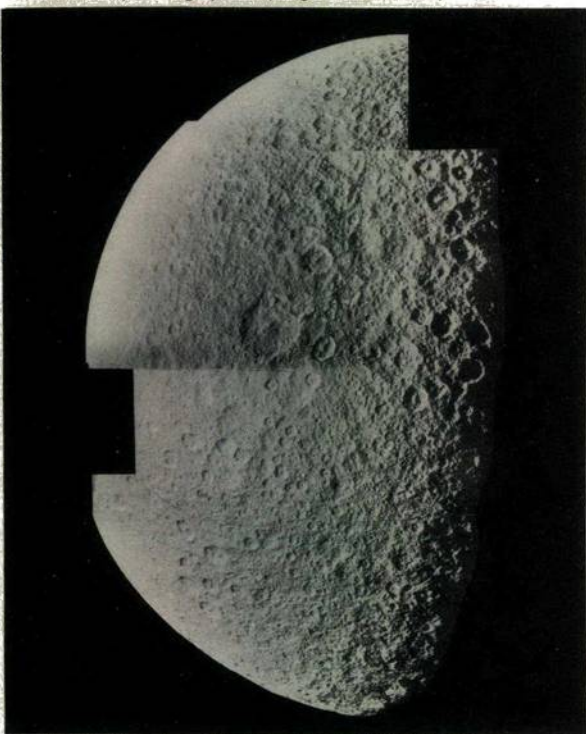
A decade or so after concept of the program, and three years after launch of the craft from Cape Canaveral, the scientists today would not have much longer to wait for this final and closest encounter. Data were pouring in at a rate which permitted only cursory glances at the highlights, while the bulk of information would have to wait to be reduced over the months and years to come. It was a case of "data overdose."

"We're in a 'gee whiz' kind of stage," said Dr. James Pollack, a scientist from Ames Research, as he participated in one of the panel programs given for members of the press. His words reflected wonderment at the treasures, at the pictures and information, unceasingly pouring in from the vicinity of Saturn. Throughout the von Karman Auditorium at Jet Propulsion Labs in Pasadena, where representatives of the media from all over the world had gathered, television screens displayed those treasures: Saturn, Titan, Mimas, Dione, new knowledge, new discoveries, instant science!

"Gee Whiz" might have echoed the sentiments of the teams of scientists, but in keeping with the conventions of their profession, the jargon of science prevailed. Why should it be that even in the climactic moments of achievement and discovery the high priests of science couch their statements in language which is beyond the comprehension of ordinary mortals?



Saturn's complex ring system (range: 8 million km.)



Mosaic of Saturn's moon, Rhea (range: 80,000 km.)

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Why the veiled language, when no threatening inquisition lurks in the background to challenge today's findings as happened with Galileo when he trained his 10-power spyglass on the planet? It appeared to him to be composed of three bodies touching each other.

Why the obscure terms, when there are none of the fears for the loss of his discovery which caused Christiaan Huygens to publish his first notation of the explanation of the Saturnian rings in cypher? A tract published March 5, 1656 contained the following proposition:
aaaaaa ccccc d eeeee g h
iiiiiii llll mm nnnnnnnnn
oooo pp q rr s ttttt uuuuu

Not until the year 1659 did Huygens restore the letters to their original arrangement and announce to the world his tested Saturn theory: "Annulo cingitur tenui, plano, nusquam coherente, ad eclipticam inclinato" which translates into: "It is surrounded by a slender flat ring, nowhere connected to the planet and inclined to the ecliptic."

It is fortunate, indeed, for the scientists, and for the space agency, that popular/mass publications have able translators — men and women who *can* communicate the important event so that hundreds of thousands can share in it. *Time* magazine is to be applauded for its lucid and articulate reporting of the flyby drama: "Rings like wobbly disks on an old car..." "Snowballs the size of Volkswagens..."

With the allocation of funds for space projects being reduced or cut outright, at a time when the hoped-for Halley comet probe seems destined to oblivion, why cannot our scientists go enthusiastically and publicly on record and be the first to extol the wonders around us in easy-to-understand words? Only in this manner can popular support that carried men to the Moon — and which alone will lead to ever more exalted ventures of space exploration — be rekindled.

Once again the eyes and ears of the world were on space science. But unlike the television play, where the story line unfolds and is resolved within a neatly packaged time-span of fifty-two minutes (allowing time for "commercial messages"), the scenario here is different. As it revealed itself on countless video monitors in the JPL pressroom — even the cafeteria — and subsequently in all too brief newspots on millions of TV screens in the homes across America and the

world, there were no quick resolutions telling "Who shot J.R."

The mystery is far deeper. Properly presented, it could strike chords in the hearts of all. Somewhere between the personality-oriented rites of the *Cosmos* series and the humorless network news reporting of an historic mission to the very edge of our solar system, there is space for the feature with the ultimate appeal: less imaging — more imagining.



The very fact that each new image, each byte of telemetered information unveils new horizons, poses new questions in turn, lies at the very heart of the exquisite drama. The ever-present thought that many of the enigmas of space may not be answered for decades or centuries to come, and that the basic underlying truths may pass human understanding, brings us closer to the mystical than we have ever been before.

How could this correspondent who, twice now, has lost his way looking for JPL in Pasadena (it is not really in Pasadena *per se*, but in the La Canada/Flintridge area) ever find his way among the alphabetically designated rings of Saturn? Before Pioneer there had only been the A, B, C, and D rings; following it there had been a half dozen or so. Now countless new rings and ringlets presented themselves with amazing clarity to the dispassionate eye of an emissary camera. Dozens, scores — more than a hundred: light rings, dark rings, parallel ones, eccentric rings, some braided, twisting, kinked....

When it was no longer possible to contain the yet unexplainable with explanations, the features were collectively termed "bizarre." It was far more than bizarre. It was breathtaking — and it needed no instant clarification. The pictures were the message. They had traveled across a billion miles of near empty

space in tiny bits and pieces, graduated in 256 digital tone values — black to white — and some had already been color-enhanced. There was plenty to show to a wide-eyed kid coming home from school on that memorable Wednesday, the 12th of November 1980.

One on whom the impact of the hour was not lost was octogenarian Clyde Tombaugh, the man who discovered Pluto. He had come to witness the flyby. Meeting this gentle, soft-spoken man was my own planetary encounter, the ultimate extension of the "grand tour." Tombaugh's presence gave human dimension and genuine humility to the experience. It felt as if he represented the link with Lowell, Herschel, Cassini, Huygens — and even Galileo himself.

The human dimension of the endeavor tends to be lost in the electronically supercharged environment where preprogrammed instruments, built years ago, perform with flawless reliability and precision, light-hours from "home." The geniuses who designed and crafted the on-board computers which silently carry our instructions to the edge of the solar system and who stored the data to be used in crisis contingencies, tend to be forgotten. While today's investigating teams are basking in the limelight of being able to report the latest saturnian discoveries, yesteryear's artisans may be standing in the lines of the unemployed — or be pumping gas.

There rests the drama; there lies the poignancy of the entire almost superhuman effort. It is a celebration of achievements past, present and future combined. This is the stuff of which history is made: the moment of truth, where science transcends technology and becomes art. Braided or eccentric rings need no longer be instantly explained or accounted for. Suffice it for them merely to exist, for us to view and appreciate. Let the mysteries dwell a while.

As on New Year's Eve, when partygoers in New York can, at 3 a.m. Eastern Standard Time, watch midnight revelers singing "Auld Lang Syne" in Los Angeles, so here too, the picture of closest approach to Titan, which boggled minds in California at 0030 hours, had left the saturnian scene 90 minutes earlier. The images of the upcoming closest approach to Saturn would, in turn, not reach humankind for another 17 hours.

So what's the hurry? Enjoy, enjoy....

Gee Whiz!

Ben Mayer
Los Angeles, CA

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Photos Courtesy Allan Seltzer—India, 1980.

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Lecturer in Astrophotography at the
Hayden Planetarium and at Columbia
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Dr. Lee W. Simon

Director of the Morrison Planetarium,
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eye
on the
sky

the great conjunction

by
Fred Schaaf

the wanderers

February offers an excellent chance to see Mercury in the evening sky and a last chance to observe Venus in the morning heavens. But by far the finest celestial sight this month will be the stunning "double planet" rising rather early in the evening by the end of February.

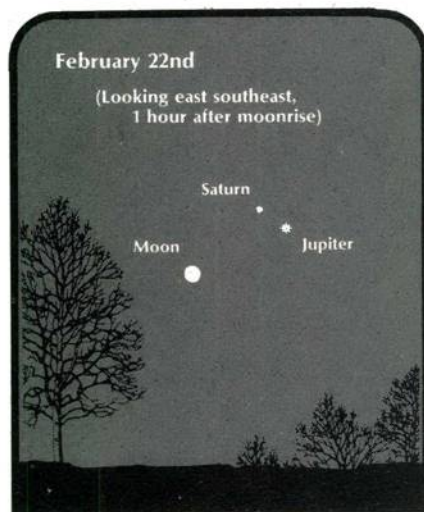
The "double planet" is formed by **Jupiter** and **Saturn**, now together in a Great Conjunction (which is actually three conjunctions). The word "conjunction" in that title is the older, looser meaning: a close positioning of two (or more) celestial objects. Most observers would agree that a 3° separation is a close one for two prominent planets, so by this old definition we might say that Jupiter and Saturn are in conjunction from November 1980 until August 1981 (which, interestingly enough, happens to span the period between the two Voyager encounters with Saturn).

Perhaps even more remarkable is their closeness from last December through this March. During this time these two giant planets remain within $1\frac{1}{2}^\circ$ of each other. Most conjunctions involve at least one fast-moving planet, and so the two objects would normally be within 3° of each other for only a few nights at most. Jupiter and Saturn, though, are both relatively slow-moving behemoths, and since both also happen to be near opposition with the Sun, their motion is now even slower than usual — in fact, even *retrograde* (moving backward).

Technically, the term *conjunction* refers to the exact moment when two celestial objects have the same right ascension — in other words, when one is due north of the other. This happens three times during the period of the Great Conjunction, and the second of these conjunctions will occur on the night of February 18-19, when giant

Jupiter passes just $1'9''$ (or a little over two apparent lunar diameters) south of ringed Saturn. That is almost precisely the same separation as at last month's conjunction, but both planets will have brightened a little, Jupiter blazing at -1.9 and Saturn at a respectable 0.8.

Both Jupiter and Saturn will be moving slightly westward — in retrograde motion — during February, and accelerating a bit. You can perceive these changes by noting the planets' positions relative to the fixed



background star Gamma Virginis (Porrina), which is very near Saturn at the beginning of the month.

The rareness of this Great Conjunction can hardly be exaggerated — the next one will not occur for 257 years! But if we take into account the similar series of conjunctions between Mars and Jupiter last year, it becomes clear that we are now experiencing a period of several years distinguished by a multi-planetary arrangement whose rareness makes the Great Conjunction seem a common event by comparison.

Next month, when Jupiter and Saturn come to opposition together, we will consider this situation in some detail.

The whole month of February will be superb for observing Jupiter and Saturn (particularly note the Moon passing by them), but only the opening days of February will be excellent for **Mercury**. To viewers in the United States, this time of year is favorable for planets in the evening sky because the angle of the *ecliptic* (the Sun's path in the sky which planets closely follow) is steep to the western horizon at sunset. Therefore, when Mercury reaches its greatest elongation from the Sun on the evening of February 1 — and for perhaps the next five nights — it will be fairly high in the west. By 30 to 45 minutes after sunset you should be able to spot it easily, gleaming like a bright gem in the twilight sky. If the first night is cloudy, be sure to look on one of the next few evenings, for this swift planet will be plunging back to reach *inferior conjunction* — passing almost between us and the Sun — and will have faded from the -0.4 it was at the month's start to only 2.8 by February 17. By then, though, it will be too close to the Sun to be observed.

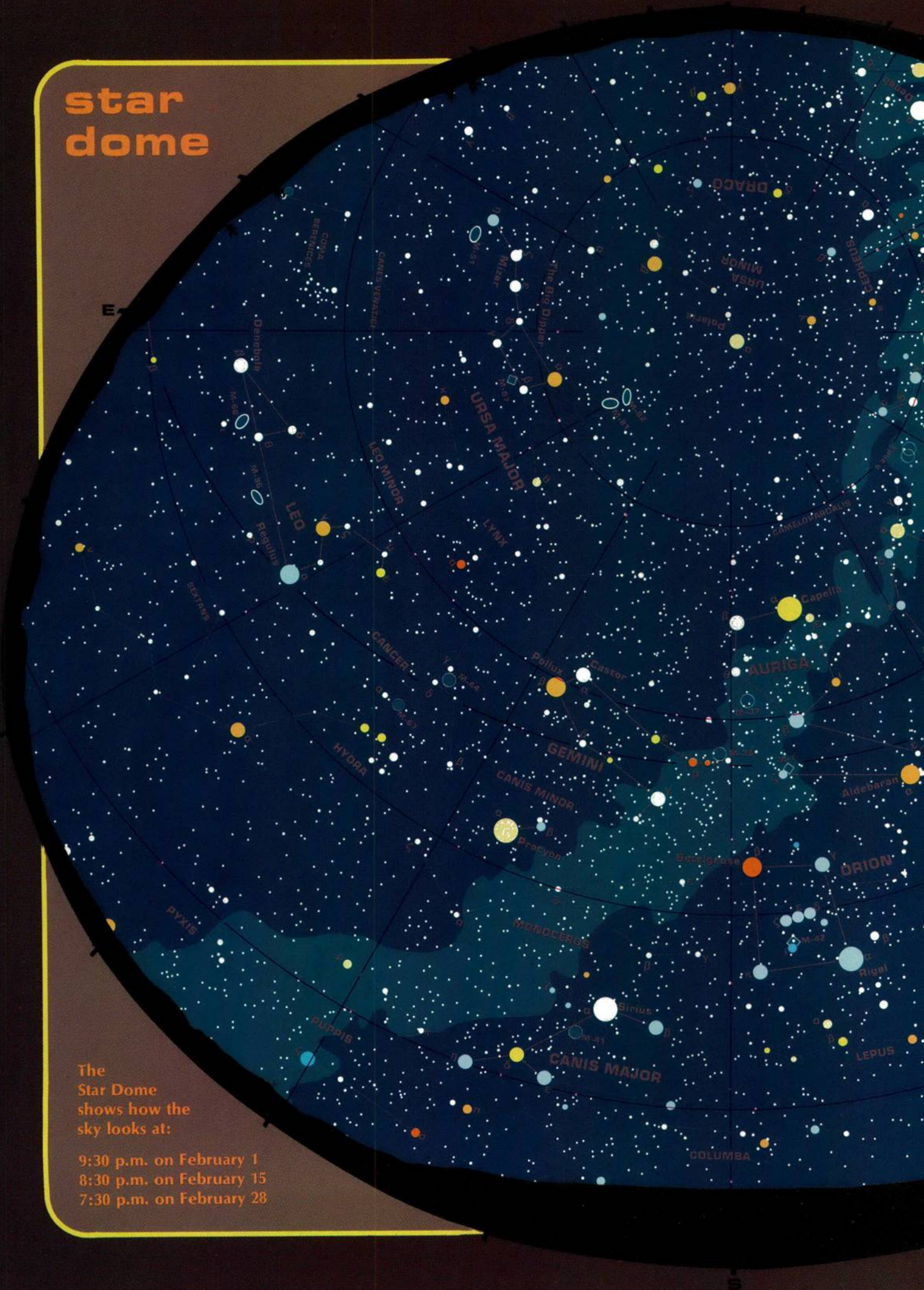
Mercury will pass 4° north of Mars on the 10th, but the two are then almost hopelessly difficult as objects of 1.2 and 1.4 magnitude (respectively) only 12° from the Sun.

Another planet we will lose to the Sun's glare this month is our brightest, **Venus**. If you are an early riser, see how late in the month you can spot Venus as the Morning Star. The position of this unmistakably bright

From a viewpoint overlooking Colorado Springs on the morning of November 4, 1980, Ray Beamer of Cascade, Colorado took this fine photo of the predawn grouping of the Moon, Venus, Jupiter, and Saturn. He used a 50 mm lens set wide open at $f/1.8$ with a 5 second exposure on Ektachrome slide film (64 ASA).



star dome



The
Star Dome
shows how the
sky looks at:

9:30 p.m. on February 1
8:30 p.m. on February 15
7:30 p.m. on February 28

february sky almanac



- 1st** Tonight, Mercury will be at its farthest apparent separation from the Sun. Look for it low in the southwestern evening sky.
- 3rd** Just before sunrise this morning, Venus and the Moon will be close together in the eastern sky.
- 4th** New Moon at 5:14 p.m. EST.
- 5th** Mars, Mercury, and the Moon form a group low in the evening sky tonight. Also: Mercury is at its closest orbital distance from the Sun (perihelion).
- 8th** The Moon is at perigee (closest to Earth) this evening: 228,792 miles.
- 10th** Very low in the evening sky tonight, you might catch sight of Mercury near Mars.
- 11th** First Quarter Moon at 12:49 p.m. EST.
- 17th** Mercury passes between Earth and Sun today (inferior conjunction), and moves into morning sky.
- 18th** Full Moon at 5:58 p.m. EST. Also, tonight and early tomorrow, Jupiter will overtake Saturn in the second of the Great Conjunction's three encounters.
- 21st** The Moon will overtake Jupiter and Saturn almost simultaneously this evening.
- 24th** Venus is at aphelion, its farthest orbital distance from the Sun. Also, the Moon is at apogee (farthest from Earth) this noon: 251,484 miles.
- 26th** Last Quarter Moon at 8:14 p.m. EST.



Downtown St. Louis lies in the foreground of Lynn Hickman's shot of the November 4th conjunction. This photo shows the Moon higher than Venus; compare it with the one on page 31, which was taken 2½ hours later — in the interval, the Moon has moved level with Venus. The exposure here was 6 seconds at f/2.8 with a 50 mm lens.

planet will be low in the southeast, very unfavorable for United States observers.

A challenging project for observers with dark skies is to try to see an asteroid with the naked eye. This month offers your best chance of the year, for **Vesta** will be as bright as 6.16 magnitude during February. If you have a star atlas, you can use the positions given in *Through the Eyepiece* to attempt this interesting feat. And while you are out under those clear country skies, look to the west after twilight for the **zodiacal light**. February is the best month for evening observation of this beautiful phenomenon, described and illustrated in the October 1980

the starry sky

Sirius, the brightest star in the heavens, stands at its highest in the

south around 9 p.m. on February evenings. **Sirius** is the dog star, source of our term "dog days," for it was once thought that those days of mid-to-late summer were sultry because **Sirius** was in the daytime sky, supposedly adding its heat to the Sun's. This brilliant light in the head of **Canis Major**, the big dog, may not add any heat to winter nights, but the glory of its blue-white splendor (sometimes mixed with many other colors) will help make you more appreciative — or at least a little more tolerant! — of the keen winter air. And it is a good starting point for a February tour of the heavens.

You will surely not need the guidance of **Sirius** to find the master of the big dog, **Orion** the hunter. **Orion** is to the right of **Canis Major**, leading his hound across the sky after several possible quarries. According to some story-tellers, **Orion**, begirt with his spectacular three-star belt, is facing the charge of **Taurus** the bull. **Taurus** is best-known astronomically for his triangular face composed of the **Hyades** star cluster and the much brighter foreground star, **Aldebaran**. Interestingly enough, if all the **Hyades** were combined, their radiance would just barely outshine **Aldebaran**.

While you view the confrontation of **Taurus** and **Orion**, compare orange

Aldebaran with a star of similar hue in the hunter's upper left shoulder, **Betelgeuse**. Isn't **Betelgeuse** a deeper red-orange? What about their brightnesses? **Betelgeuse** is usually somewhat more brilliant, but it is a variable star with a potentially large range. Whereas **Aldebaran** varies only slightly, **Betelgeuse** has on at least one occasion exceeded all stars visible from latitude 40° N except **Sirius**, while on other occasions it has dimmed so far that it barely outshined the stars of the belt. This star varies over a period of about six years, but there are many surprising fluctuations of much shorter period. How bright do you estimate **Betelgeuse** is tonight?

Farther west than the **Hyades** is another possible object of **Orion's** pursuit: the lovely **Pleiades** star cluster, also known as the Seven Sisters. North of the **Pleiades** you can still spot the hero of autumn skies, **Perseus**. But if we return back to our base point of **Sirius**, we find still brighter stars than these high above the dog star.

Another "dog star," the brightest light in **Canis Minor**, is **Procyon**, surely one of the most neglected of our first magnitude stars — not only because its constellation is small with few stars, but also because it tends to be compared (as we are doing now) with

incomparable Sirius. Notice that Orion's dogs are exactly separated by a rather bright "river" — a prominent section of Milky Way. Here, mostly inside the triangle of Sirius, Procyon, and Betelgeuse, is faint **Monoceros** the unicorn. There aren't too many naked-eye stars to see here, but binoculars can begin to reveal some of the misty and mystical patches of star clusters which adorn both the one-horn and **Puppis**, a constellation to the east and south of Canis Major which was once part of the now disbanded old constellation Argo (the ship).

Above the dogs we find **Gemini** the twins, featuring the superb duo of **Pollux** and **Castor**. Among all the splendors of the winter constellations, not the least is that two such bright stars should be so close together. Castor is only a bit brighter than the stars of Orion's belt, but Pollux is considerably more brilliant and the two are only about $4\frac{1}{2}^\circ$ apart. As a whole, Gemini is one of the brightest constellations, and it includes M-35, a fine star cluster easily visible to the naked eye on dark skies.

The most northerly of the many bright stars of the winter constellations is **Capella**, in **Auriga** the charioteer. Capella is at the top of the **Winter Hexagon** or the **Heavenly G**, giant asterisms formed by the same set of brilliant stars. The Winter Hexagon is formed by straight lines that connect Capella, Castor, Pollux, Procyon, Sirius, Rigel (the brightest star in Orion), Aldebaran, and back to Capella — with Betelgeuse inside, somewhat off from the center. The Heavenly G is made with curved lines connecting the same stars, but with Aldebaran connected only to Capella (not to Rigel) and Betelgeuse now included to make the horizontal line of the G. How easy is it for you to see these asterisms, so vast and so distractingly clotted with extraneous bright stars? Perhaps these star patterns are best seen from large cities, where artificial lighting drowns third and even second magnitude stars.

The oncoming wave of spring constellations in the east includes dim **Cancer** with its fuzzy naked-eye patch — the **Beehive** star cluster — and, below Cancer, the small, perfect head of **Hydra** the sea-serpent. Finest of these rising constellations, however, are **Leo** the lion (with bright Regulus) and in the northeast the unmistakable pattern of the **Big Dipper**.

skylore

Castor and Polydeukes (in Latin Pollux), the most famous of all twins, are the Greek mythological characters immortalized in the constellation Gemini the twins. The circumstances



of their conception and birth are very strange, even for mythology, and more than a little confused by variant accounts. At the very least we know that their mother was Leda, ravished by Zeus in the form of a swan. This event of aviary rapine is powerfully described in Yeat's poem "Leda and the Swan," which ends by asking, "Did she put on his knowledge with his power/Before the indifferent beak could let her drop?"

Leda, however, happened to be the wife of King Tyndareus, and there is — understandably — confusion as to whether Castor was his son or Zeus's. On the one hand, Castor and Pollux were known as the Dioscuri, meaning sons of Zeus; on the other hand, Leda gave birth by producing two eggs (yes, swan-eggs!) which hatched producing (it is said) from one the mortal children of Tyndareus — Castor and Clytemnestra — and from the other, the immortal children of Zeus — Pollux and Helen.

Both Clytemnestra and especially Helen, the fairest of all women, are famous figures in the story of the fall of Troy. It is less well-known that before the fateful act of Paris brought her to Troy, Helen was kidnapped once before. In the earlier incident, mighty Theseus together with a friend carried Helen off, but she was rescued by her brothers Castor and Pollux, who pursued them and coincidentally arrived when Theseus was away.

Castor, who became a great charioteer, was the first person ever to ride a horse, while Pollux was the greatest boxer of the time. They played minor roles in several great adventures such as the Argonauts' quest for the Golden Fleece. The twins' one very memorable moment in that expedition came on the journey home

when a great storm threatened to overwhelm the Argo. It is said that Orpheus, the greatest of musicians, played his lyre and his melody stilled the waves raging about the ship, while at that very same moment a star or radiant flame appeared over the head of each of the twins.

Ironically, Castor and Pollux came to woe at the hands of another set of twins, Idas and Lynceus. Lynceus, as his name suggests, could see as sharply as a lynx, and he used that ability to deadly advantage in the quarrel with the Dioscuri. There are many different versions of the fight, but the final result was Idas and Lynceus dead, and the mortal Castor also slain. So great was Pollux's love and devotion to his brother that he refused immortality unless he could share it with Castor. Zeus granted the request, but once again the accounts differ as to exactly what the special arrangement was. The happiest version perhaps is the one that says Castor and Pollux, forever inseparable, must spend half of their time on Earth and half in heaven.

The Romans, who had their tale of the twins Romulus and Remus, greatly venerated Castor and Pollux and claimed that they sometimes appeared on magnificent white horses to help a Roman army. Because of the incident on the Argo in the storm, the Dioscuri were also reputed to be the protectors of sailors. The lights which appeared over the twins' heads were associated with what we now most often call St. Elmo's Fire — an electrical discharge which appears when the potential is high as an eerie radiance on tall, pointed, and isolated objects — such as the masts of a ship. The phenomenon was often called Ledeian Lights in ancient times, after the two sons of Leda.

ASTRONOMY IN FOCUS

Velikovsky Redux

Sir/James Oberg's letter (December 1980) shows that his perception of Velikovsky's ideas remains as one-sided and slipshod as it was in his article (July 1980). But in demolishing his thesis, i.e., that Velikovsky made no valid predictions about the solar system (Oct. '80), I have hardly avoided "the substantive issues" that Oberg raised.

If worlds really did collide, whatever the detailed effects, then Oberg's article is irrelevant. None of the errors Oberg cites serves to dispel Velikovsky's central thesis of planetary collisions in historical times. While it would have been helpful if Velikovsky's predictions had been more accurate, his historical point of departure is not well suited to quantify expectations.

Velikovsky's record is certainly no worse than that of scientists whose expectations are dashed by each new discovery from Voyager. That NASA scientists do not report explicit corroboration for Velikovsky does not mean that none exists. Oberg is quite wrong if he believes his listing of supposedly failed predictions justifies a dismissal of Velikovsky's ideas. Mainstream scientists tend not to be looking for Velikovskian interpretations of their data.

As Arthur Koestler observed: "The recurrent, embittered controversies in the history of science prove over and over again that the same data can be interpreted in different ways and reshuffled into different patterns." Radioisotope dating and the thermal state of Venus, for example, are susceptible to alternate interpretations. In fact, consistent with Velikovsky's indication, and contrary to all conventional expectations, Venus is observed to radiate 15% more energy than it receives. This possibility was shown

quantitatively by Dr. George R. Talbott in 1978 in *Kronos* IV, 2.

According to Thomas Gold, "Lunar science is so stuck in misperceptions that it's an absolute disaster." Almost 90% of the moon rocks returned to Earth are still crated and unexamined. Given our state of knowledge about the Moon, Oberg's blanket dogmatic rejection of Velikovsky's claims is premature.

The value of arguing technical issues with one who cannot tell the difference between a prediction and an affirmation of the conventional wisdom (Velikovsky's "Jupiter is cold...") and who does not understand the difference between heat and temperature (regarding the thermal state of Jupiter) is questionable. By insisting that Velikovsky was wrong about Jupiter being cold, Oberg seems oblivious to the fact that a cold body can give off more heat than it receives from the Sun. Begging Mr. Oberg's pardon, no planet whose surface is presumably liquid hydrogen can be described as hot.

Other of Oberg's misperceptions would include: 1) in potassium/argon dating, while melting releases argon, most escapes by diffusion long before dating, thereby invalidating the assumed retention; 2) since thermoluminescence (TL) dating and radioisotope dating measure different time spans, neither invalidates the other; 3) Walker's reported rationalization that solar heating of subsurface material would explain the TL data is fallacious because during a lunar day, the surface would not get hot enough to produce a TL-datable event.

Oberg seems more intent on drawing attention to himself as a would-be giant killer than on finding knowledgeable resolutions and concretizing new pathways. The

same accolade recently accorded T. Gold applies as well to Velikovsky: "He has been wrong, he has been right, but invariably he has been creative and provocative." The last word on Velikovsky has yet to be heard.

Leroy Ellenberger
Associate Editor, *Kronos*
Landover, MD

Time Scales in Collision

Sir/In response to any article critical of Velikovsky, his defenders rush in with a combination of logic and illogic, fact and fantasy, mixed with a heavy dose of vituperation and personal insult for the unlucky author. While the personal attacks are best ignored, I feel compelled to point out one basic error promulgated by Ellenberger and Greenberg in the October 1980 issue.

Velikovsky's primary break with physical science concerns time scales: he postulates that events on the Earth and planets took place during the past few thousand years, events more conventionally believed to have required millions or billions of years. Recently, our ability to use the physical and chemical state of rocks to derive their ages has vastly improved, and these ages confirm the "geological" time scale. Thus the pro-Velikovsky position can only be defended by dismissing or discrediting virtually all quantitative measures of age.

For older materials, such as the lunar rocks and soils, the ages are based on the most exacting analyses of a variety of radioactive elements and their "daughter" products (see, for instance, the article on the Caltech laboratory of Gerald Wasserburg in the May/June issue of *Science* 80). The "age" is the time since the sample last experienced escape of the daughter products; in

most cases, it can be understood as the interval since last melting. In the case of the lunar rocks, these ages as determined by several different techniques are almost all greater than 3.0 billion years, clearly excluding recent melting or other violent disruption of the surface.

Ellenberger, like Velikovsky, chooses to misunderstand, so let me be explicit: the "ages" do not refer to the original crystallization, but to the most recent melting or, for the more volatile daughter products, to the most recent shock. There is no known mechanism — including electric discharges — to accelerate the decay process. Yet to produce the observed amounts of daughter products in a few thousand years instead of a few billion would require a sustained recent increase in the radioactive decay rate by a millionfold. Disturbances can decrease the apparent age, but not increase it. It must require a remarkable mental flexibility on the part of Ellenberger, Greenberg, et al. to maintain their belief in Velikovsky's hypothesis in the face of such powerful evidence — and I stress that these measured properties of rocks are hard data, not hypotheses attributable to a preconceived notion about the ages of the planets, as they are inclined to assert.

I emphasize this matter of quantitative geological dating, because it applies to the terrestrial record as well as the astronomical. These techniques have advanced to the point where we can date volcanic eruptions and climatic changes, thus testing directly Velikovsky's claims of violent activity on our planet in about 1500 and 700 B.C. While local events such as the eruption of Thera in the Mediterranean can be identified, the recent global catastrophes he postulated simply didn't happen, whether due to a planetary near-collision or any other cause.

Velikovsky and his followers are an anachronism — a carryover from the qualitative and descriptive scholarship of a century ago, before quantitative tests had been developed to discriminate among concepts of "natural philosophy." It is too bad Velikovsky could not have applied his fine mind to the great questions of nineteenth century science, to which he was philosophically attuned, rather than wasting his talents on a confrontation with today's sophisticated physical science, which he never understood.

David Morrison
University of Hawaii
Honolulu, HI

Velikovsky (yawn)!

Sir / I'd like to put a stop to the Great "I Said It First" Debate. To Messieurs Oberg, Greenberg, Ellenberger, Sagan, I want to say: "You're boring me to death."

I don't care. I don't care how old you think Venus is. Nor do I care who said Clavius is awash in lethal radiation. Nor whether Shea Stadium was formed by the Earth's passage through comet Kohoutek. It may shock you, but I don't even care how many angels can disco on the head of a pin.

Gentlemen, you're not debating; you've got a nasty little squabble going. As for me, I don't care. In my backyard there is a small building. Most who pass by think it is a tool shed. But I have a secret. In that building there is a large white telescope, and on cool fall evenings I like to sit and look at the sky. I especially like to look at a marvelous great spiral galaxy called M-31.

A strange, unexpected thing happens: when I come inside the house at the end of the evening, I am at peace. I don't yell at the dog who blocks the hall in his sleep for the thousandth time, nor at my son who is still on the phone, nor at my

wife who usually threatens divorce if I keep forgetting to take out the garbage.

I feel secure. I am reassured. Not because I have discovered the real nature of the redshift, but because I finally have the answer. Millions of years after all of us, gentlemen, have vanished, my lovely great spiral in the night sky will still be there, turning ever so slowly. All our questions and answers and fights and pettiness will have altered its course *not at all*.

Like Dorothy before the Wizard, we are the small and meek and we will not pass this way again. Our lives are precious and short, and if we hope to accomplish deeds on the Earth, let them be good ones. THAT is the truth.

Gentlemen, I am an AMATEUR astronomer. I will leave the squabbles to the professionals.

John W.H. Simpson
Princeton, NJ

Ooops

On pages 40 and 41 of the December issue, the captions for the two photos were accidentally transposed. Sorry!

behind
the scenes

close encounters with science

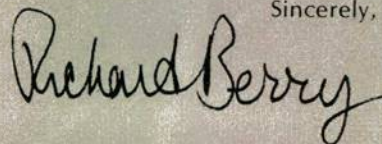
For the scientists at JPL, "instant science" under the glare of TV lights was clearly stressful. They had no time to study data carefully, too little time to discuss it with their colleagues, barely enough time to check important references, and no chance to do more than back-of-the-envelope calculations. "I'll lend you an envelope," joked one reporter to a tired scientist who didn't have a ready answer.

Small wonder that so many "mysteries" were reported in the first days after the flyby. Scientists habitually emphasize what they don't understand, and thereby sell themselves short. What impressed me was how many discoveries were quickly assimilated, and how the scientists used the new discoveries to modify, enrich, and refine their conception of Saturn and its system of rings and satellites. Our increased understanding makes the mysteries that remain all the more wonderful.

In contrast, the debate over Velikovsky's hypothesis, one that has "ragged" in our Forum and In Focus columns since last October, seems dull and, well, to be honest, tiresome. While the debate could obviously be continued forever, I don't expect any blinding revelations. With this issue, therefore, I am closing the debate. If you are interested in following it, I'd suggest you try future issues of *Kronos*.

On a more pleasant note, NASA has released a colorful 198-page book called *Voyage to Jupiter*. It costs \$7.50 and you can order it as "NASA SP-439" from the U. S. Superintendent of Documents, Washington, DC 20402, or at any U. S. Government bookstore.

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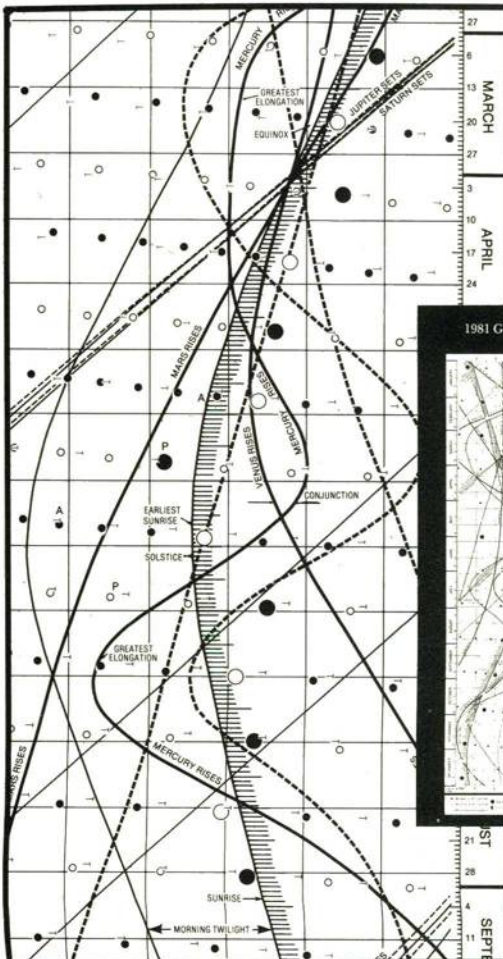
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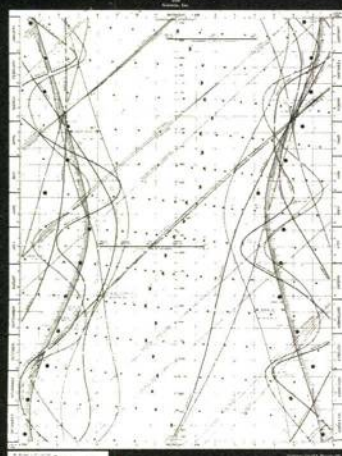
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a cold camera for astrophotography

by
Jack Newton

photography
in
astronomy

A cold camera is one of those pieces of "ultimate equipment" most astrophotographers aspire to own — and I'm no exception. Although sometimes they're a pain to use (literally, on occasion), they offer the most practical solution to the twin problems of reciprocity failure and shifting color balance. Figuring I had enough experience with "warm" cameras to use one well, I decided to build a cold camera. (Sure, I could have bought one, but what's the fun in that?)

However, before we wade into the details, let's review what a cold camera is supposed to do and how it works.

Any photographer who goes beyond the "instantaneous" exposures of snapshots discovers reciprocity failure. This term simply puts a name to what happens when, with exposures that run longer than a few seconds, twice as much exposure (say) no longer yields twice as much effect in the film emulsion: the reciprocal relationship of intensity and time fails to hold true.

When light hits a photographic emulsion, it produces changes in light-sensitive crystals that decay within a few seconds. If the image is bright enough, these crystal changes will consolidate into a lasting latent image that, after suitable treatment (i.e., photographic development), will be the permanent negative image we're all familiar with.

In ordinary photos, enough light strikes the emulsion to "attach" the latent image during the exposure. But astronomical light levels are so low that the image decays before sufficient light has kicked the crystals hard enough to make the latent image "stick." Your picture, in effect, leaks away as you take it — a slow way indeed to build up a picture!

The best way to arrest the decay process is chilling the emulsion: this lengthens the decay time from a few

seconds to many minutes. Ordinary (water) ice isn't cold enough and makes an incredible (well, soggy) mess when it melts. Frozen CO₂ (dry ice) is much colder and evaporates without residue — making it the usual choice for a cooling agent. Besides, it's reasonable in price and *relatively* safe and easy to handle — though it doesn't store very well.

Although dry ice is very chilly (-109°F or -78°C), you'll never get your film this cold: enough warmth manages to seep in that the film doesn't get much colder than -50°C (-58°F) — luckily, as it turns out, for this is nearly the ideal temperature for putting reciprocity failure to sleep.

How does chilling the film help color rendition in long exposures? Color film is made from three separate black & white emulsions, each sensitized to a different primary color and each having its own reciprocity failure. Because the failure rates don't match, colors will shift during a long exposure — sending the overall color balance awry. When you chill the film, the reciprocity failure of all layers equalizes and a correct color balance

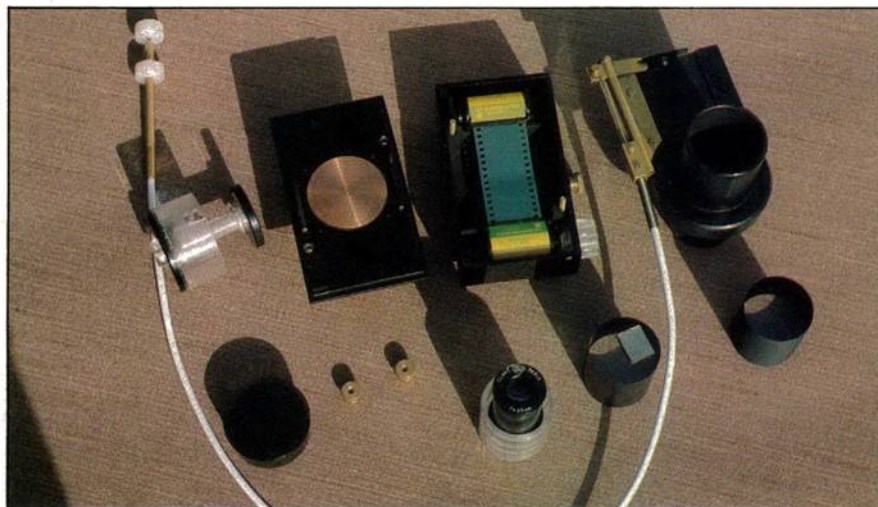
comes out in development.

Three Designs

Photographers have developed three basic models of cold camera: the optical-plug, the vacuum-chamber, and the dry-gas varieties. Behind the film plane, all three are pretty similar — the film presses against a piece of cold metal. Their chief differences lie in how they keep the inevitable frost and damp from either degrading the image or damaging the film itself.

The optical-plug models have low-conducting clear plastic pressed tightly to the emulsion of the cooled film. Frost cannot form directly on the cold emulsion and the plug's 2-inch thickness cools sufficiently slowly to keep the front of the plug from frosting over during the exposure — at least in dry climates.

Here you see the main components of the optical plug cold camera. Back row, from left to right: cable release, ice chamber cap & plunger, camera back with copper disk showing, camera body, shutter assembly. Front row, from left to right: body cap, two brass lock nuts, eyepiece holder plug, focusing plug, picture-taking plug. All photos by the author.





M-15 is a globular cluster 40,000 light-years away in the direction of the constellation Pegasus. With a visual magnitude of about seven, it's even visible to the naked eye. This photo was taken on 400 ASA film with the optical plug version of the cold camera. The telescope was a 16" f/5 Newtonian, the exposure 16 minutes.

The vacuum-chamber design replaces the solid plug with a hollow chamber from which the air is pumped. A glass port at the front end lets in light and the back end seals tightly against the film. The vacuum serves to insulate the front port and prevent moisture from condensing on the cold film.

Dry-gas models are similar to the vacuum-chamber ones, except the chamber is filled with a gas, usually dry nitrogen or ordinary air, having a very low water vapor content. (For a full rundown on cold camera types, see "Cold Cameras," *ASTRONOMY*, February and March 1977.)

The Mark I

After due thought and some rough figuring, I decided the optical plug design would be easiest to make and would keep operating troubles to a minimum. A friend of mine, George Ball of Victoria, B.C., had built several

cold cameras and so I sought out his experience.

One big drawback with conventional cold cameras is that you have to pre-cut the film, align it to fit the optical window, and handle it in total darkness. During the process, it's hard to keep the film free of dirt and fingerprints, and afterwards those little bits of film often can't be developed commercially.

Because of this, I wanted my cold camera to take film in cassettes like a conventional camera and to be somewhat tolerant of stray light. George and I came up with a camera that would use his previously designed shutter and optical plug. The design quickly took shape:

The camera body is made from a 1/8" clear plastic sheet, painted black. Well into the construction, I found some opaque black plastic and used it here and there in the design.

The winder is a short piece of machined plastic which turns the spindle of the take-up cassette. We installed a cam on it which rotates as you advance the film. This keeps the film moving in only one direction and it goes "click" as you wind off each frame.

The back of the camera (containing the dry ice compartment) attaches to

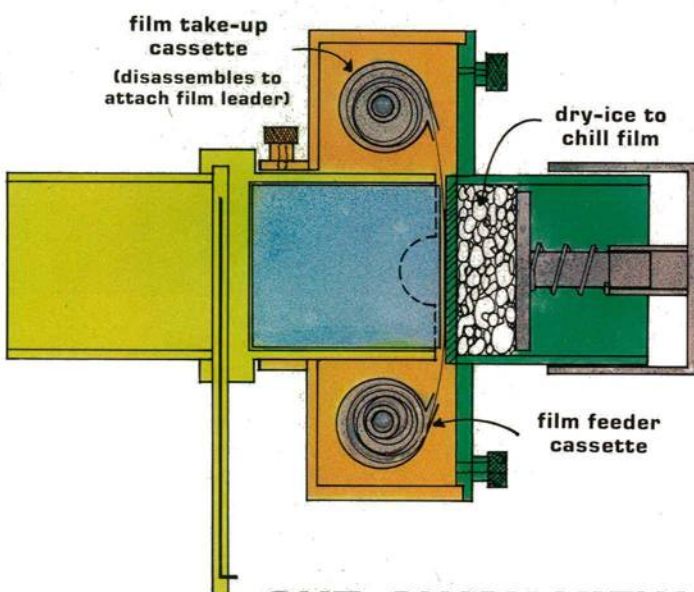
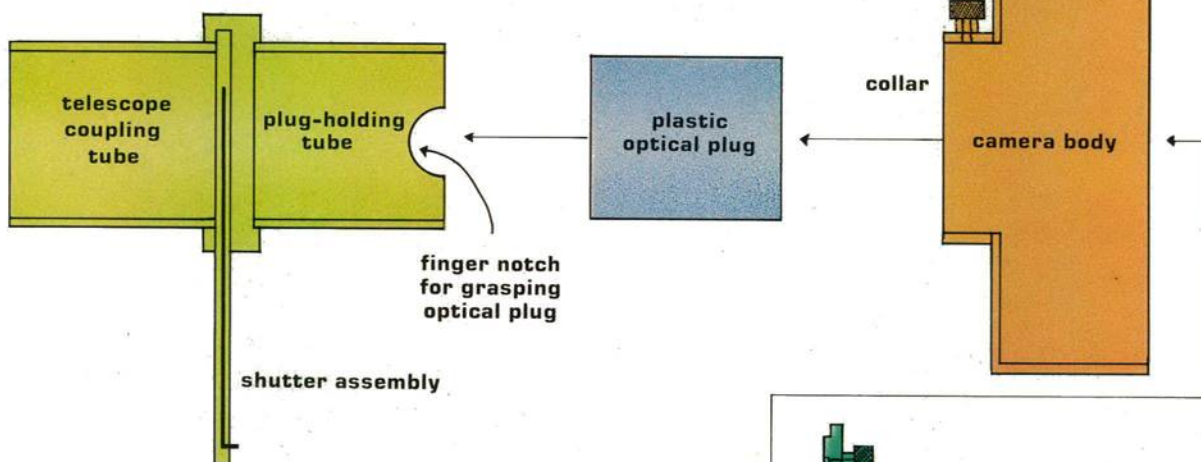
the body with two brass bolts. For good conductivity, we cemented a 2" diameter copper plate to a length of 2" diameter plastic tube and mounted it sticking through the camera back. The tube holds the dry ice, and the copper disk insures fast and efficient chilling of the film. A bayonet-lock cap (with a spring-loaded plunger) holds the dry ice against the copper plate during the exposure.

On its shutter side, the camera body has a collar with a brass lock screw that holds the plug in place against the film. To keep film in the body from being exposed when the camera isn't attached to the plug and shutter, we made a removable body cap (from plastic sheet and 2" tubing) to cover the hole where the plug enters.

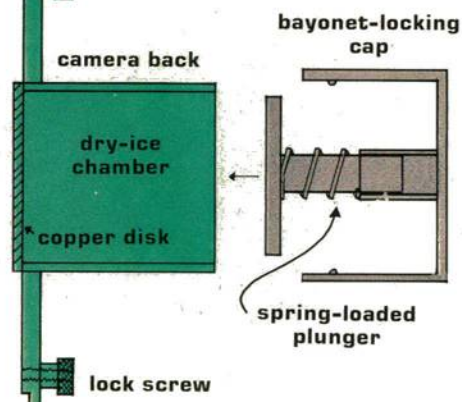
The shutter is aluminum and slides in a track; a cable release constructed of bicycle brake cable opens it. Protruding to either side of the shutter is a piece of 2" plastic tube, two inches in length and painted black. One piece slips into the 2" rack-and-pinion focuser of my telescope; the other holds the optical plug.

We made the plug from a sheet of 2" thick plastic stock by cutting it oversize and roughly circular with a band saw and then finishing it off on a lathe. The plug holds the film tightly against the

EXPLODED VIEW



CUT-AWAY VIEW



COLD CAMERA

J. Newton G. Ball

copper plate at the back of the camera.

Focusing is tricky, so we glued a piece of ground glass to the face of a duplicate plastic plug. The glass has one edge beveled at 45°; this is centered on the face of the plug. (In use, you adjust focus until the knife-edge of the glass gives the "null result.") I also made a "dummy" plug for locating the object. It holds an eyepiece and fits into the shutter assembly where the optical plug goes.

In the Field

After two short weeks of work, the camera was ready for testing; I worked out the following procedure for taking a photograph:

First, attach the shutter assembly to the telescope's focuser and insert the eyepiece plug. Locate a medium-

bright star near your subject. Remove the eyepiece plug and replace it with the ground-glass focusing plug. Carefully focus the star and lock the rack-and-pinion focuser. Then reinsert the eyepiece plug and center the desired object. Close the shutter. Next, find a suitable guide star and center it on the cross hairs of your guidescope.

Carefully clean the picture-taking plug and insert it in the shutter assembly. Remove the body cap and place the camera back over, but not touching, the optical plug and wind the film. (Don't press the back onto the plug when you do this unless you like scratched film.) With the frame advanced into place, gently push the camera down onto the plug and lock it

In the diagram above, you can see how all the components of the camera fit together. The construction materials were mainly plastic sheet and tubing, with a few assorted metal parts. Illustrated here is the optical plug design; in the vacuum chamber model, the plug-holding tube is modified to become an insulating chamber from which the air is pumped.

in position with the collar screw.

Spoon crushed dry ice from a thermos — work fast and you won't need gloves before the spoon gets too cold to touch — into its compartment behind the copper plate, then attach the cap. (Warning: If dry ice touches your skin, it can cause painful frozen spots.)

Re-center your guide star and open



NGC-6992 is the eastern of the two main filaments which together make up the Veil Nebula in Cygnus. It is the remains of a prehistoric supernova explosion that ripped off the outer layers of a massive star. As in the photo of M-15 two pages back, the film was 400 ASA, the telescope a 16" f/5 Newtonian, and the exposure 18 minutes. North lies to the left.

the shutter to start the exposure. When it's finished, flick the shutter closed. Remove the camera from the shutter and plug and quickly body-cap it to prevent light leaks. Open the ice chamber and dump any remaining dry ice back into the thermos.

Blow hot air from a hair dryer onto the camera to thaw it before you advance the film. (This warms the film to make it flexible again as well as removes excess moisture which might gunk up the emulsion.) When dry, wind the crank to advance the film, and repeat the process on the next object.

The Mark II

I have used the optical plug camera for over a year and by now have taken more than 60 photos with it. The camera isn't flawless, however; two problems have cropped up. Dust is very difficult to remove completely from the surface. I even used a

Zerostat to remove the static charge electronically from the plastic plug — which greatly reduced the problem. But however persistently and carefully I tried to clean the plug, tiny specks of dust would unpredictably appear on the photos.

The second problem was scratches — hundreds of them — on the soft plastic plug. They gradually appeared after repeated plug-cleanings and diffused the light passing through the plug to cause a slight loss of picture quality.

Both problems were very minor in comparison to the tremendous gain in film speed and overall picture quality. But as I wasn't entirely pleased, I decided to replace the optical plug with a vacuum chamber.

So we removed the 2" tube that held the plug and cemented a glass window (wrapped around with heater wire) on its shutter end. On the other (film) end went an opaque plastic plate with a rectangular opening cut in it, just a little larger than a standard film frame (24 x 36 mm). To insure an airtight seal, we cemented a silicon bathroom caulk gasket into a groove cut around the edge of the plate.

For a vacuum pump, I used an old refrigerator compressor. It connects to the chamber with standard 1/4" hose

through a nipple in the side of the film chamber.

My set-up procedure remains much the same: I advance the film, push the camera back onto the chamber gasket to make a good seal, and turn on the pump. In about 20 seconds, the chamber is pumped out and the gasket has pinned the film to the copper plate at the back of the camera.

I leave the pump running during the exposure, though air leaks haven't been a problem. The silicon gasket remains completely soft and flexible at working temperatures and under a moderately hard vacuum. As for dust, any that settles on the glass window lies inches away from focus and can't leave marks or shadows on the film.

The great thing about this whole project is that it cost less than \$25 — except for the vacuum pump which was free! The photographs speak for themselves, and I hope others with sufficient astrophotographic experience will make the step into cold camera astrophotography.

Jack Newton has been doing astrophotography for many years; his cold camera is a recent project. Anyone wanting more details about it can write him at: 4204 Morris Dr., Victoria, B.C., Canada, V8X 4G8.

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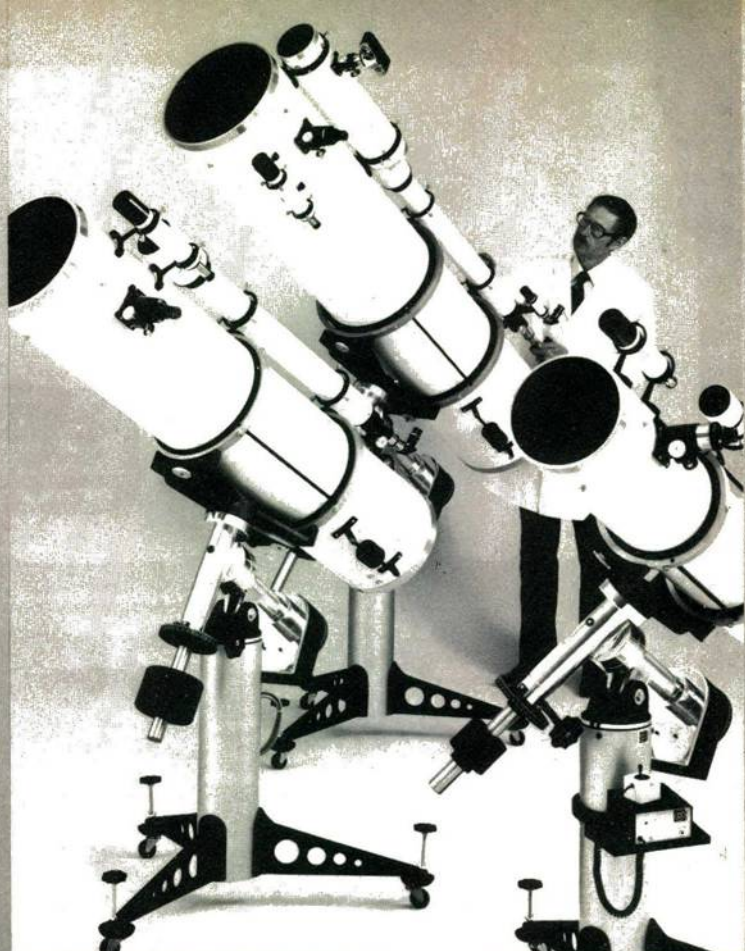
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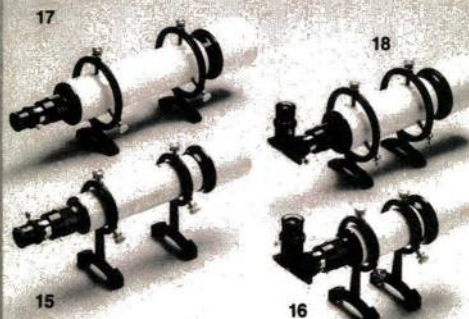
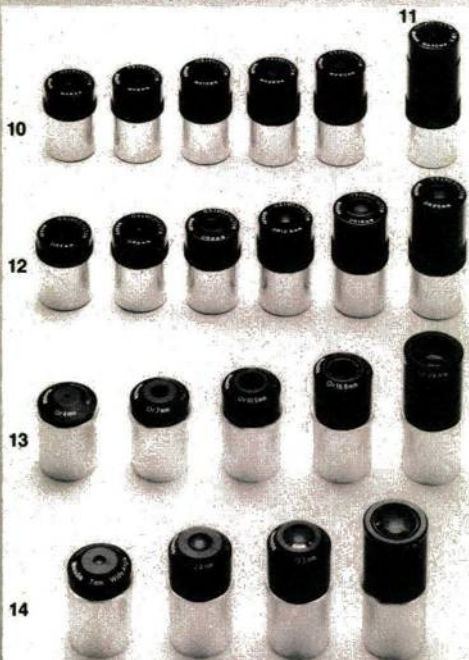
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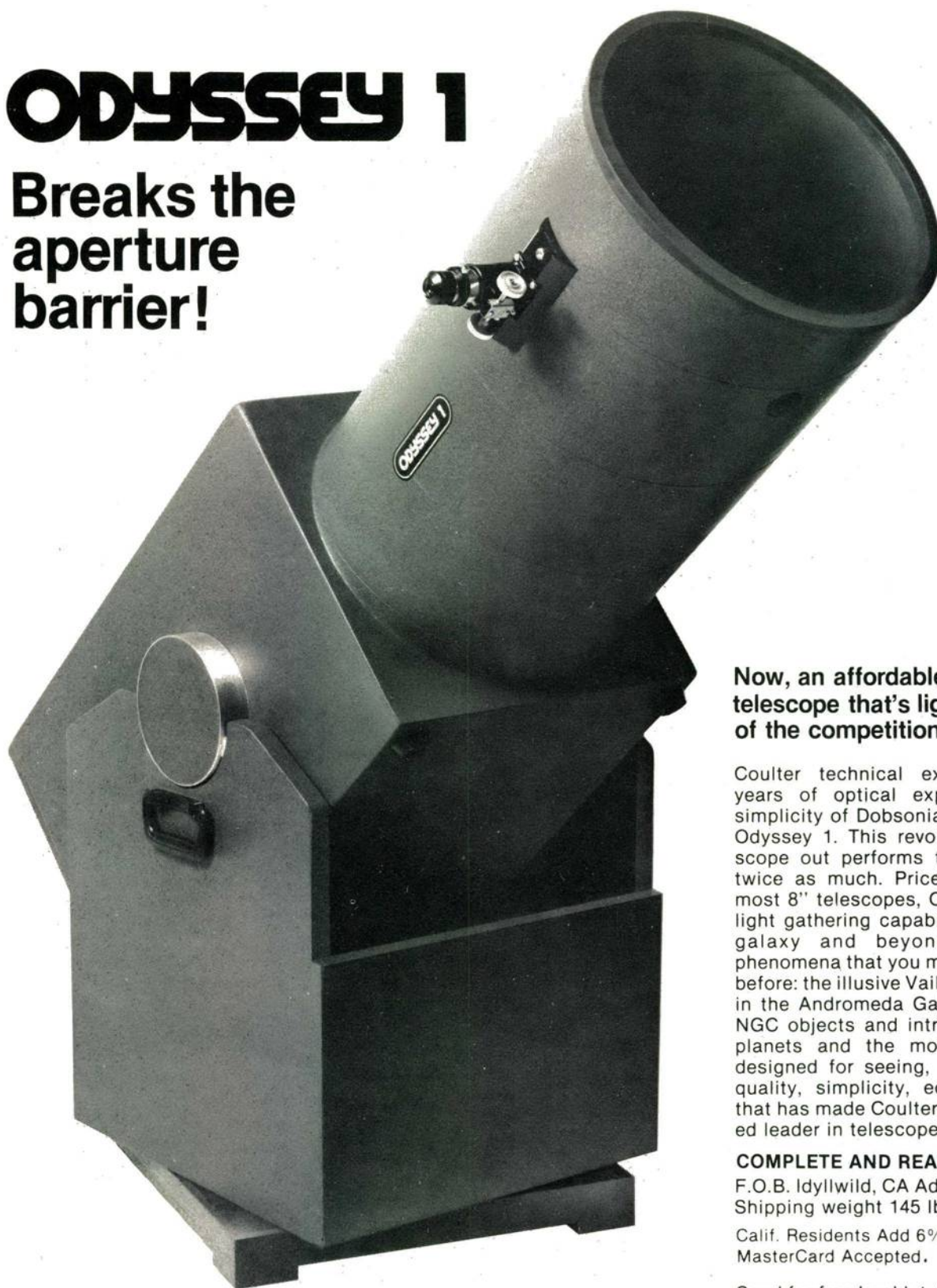
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all about telecompressors

by
Stephen D. Greenberg

equipment
atlas

Are you one of those telescope owners/users with a folded catadioptric system of f/11 or thereabouts? Or, moldering away somewhere in a dark closet, do you have the last generation's contribution to popular astronomy, an f/15 or f/16 small refractor?

If so, you've probably given up the idea of attempting to observe — or even photograph — the more spectacular Messier objects because they're too dim at the high magnifications you must use, or because they didn't fit into your instrument's small field of view. Maybe, too, you've noticed there seem to be disappointingly fewer stars visible in the field compared to an f/6 Newtonian of equal aperture.

Among the ads that tout telescope accessories are some for an item called a *telecompressor* — and from the ad copy, they sound like exactly the thing to end all your problems. So you wonder, "Should I get one or not? Will it solve my problems, or just add to them?"

First the good news: You get a faster effective focal ratio. A slow f/ratio, long-focus telescope can be turned into a visually richer (although not necessarily "richest") field instrument. Extended objects appear brighter because their light isn't spread thin through overmagnification. Photographic exposure times decrease. Telecompressors can give the advantages of a short focus reflector, without as much coma: they seem to work very well on Maksutovs and Schmidt-Cassegrains.

Moreover, shorter exposure times mean you don't get as tired when guiding. Going to f/7 from f/10 results in exposure times dropping from 45 minutes to 20 — over half! Visually, the telescope becomes better suited for comet sweeping, Milky Way views, and Messier object viewing.

O.K., so why doesn't everybody use

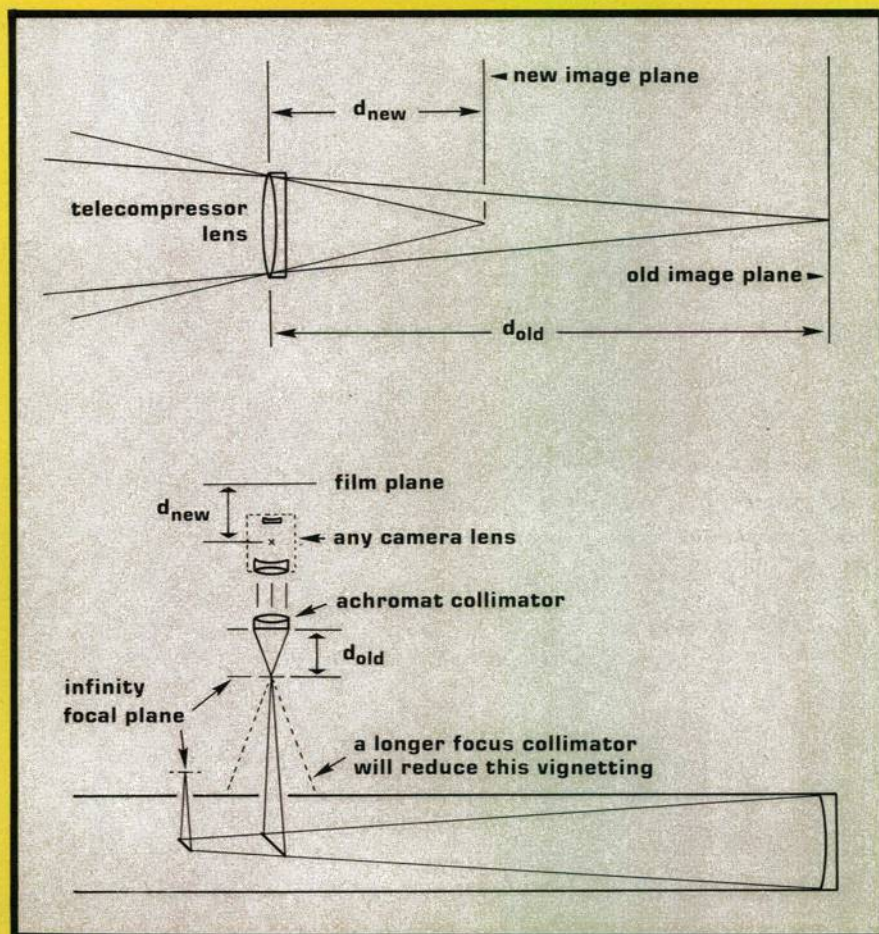
one of these things? Despite undoubted advantages, the picture isn't wholly rosy: if you don't choose one carefully, severe vignetting (loss of image brightness and contrast at the edge) will occur. Additionally, you can get some coma at the edge of the field of view and less crisp images at the center. Newtonians and refractors especially will demand substantial modification if you want to avoid vignetting and coma. Lastly, telecompressors don't seem to work well on small, but fairly bright, diffuse

sources, such as the Ring Nebula in Lyra, or other tiny nebulae.

Designing Your Own System

Within certain limits, just about any positive lens could be placed in the exit beam of a telescope and work as a telecompressor more or less successfully. However, an improperly chosen telecompressor/telescope combination will suffer from severe vignetting, lack of image contrast, field distortion, coma, or chromatic and spherical aberrations.

In general, both for viewing and



photographic purposes, telecompressors work best on instruments having a parallel — or nearly parallel — exiting light beam. A light cone that converges at an angle of approximately 10° or less will work best. In practice, this means focal ratios of f/6 or higher.

"Flat" image contrast can result when you add a telecompressor to a system. Generally, this is due either to multiple internal reflections or to large thicknesses of glass in the light path, or both. For best results, use only coated lenses and as few elements as, in your opinion, give a desirable image.

Using a simple positive lens as a telecompressor will almost certainly introduce chromatic aberration. Avoid it by selecting only well-corrected achromats for your telecompressor candidates. Binocular (or finder scope) achromats are commonly available and good for this purpose, since they are designed to work with parallel — or nearly so — incoming light rays. This is more or less what you get when you buy a commercial telecompressor. Short-focus camera macro-lenses, or darkroom enlarger lenses, are also excellent telecompressor candidates.

Whatever your telescope type, the first step is to decide where your telecompressor should go. Keep the following in mind: 1) the lens should be wide enough so that the entire diameter of the light beam exiting from the objective lens or mirror will pass through it, and 2) the lens should be mounted where the converging cone of light just fills its clear aperture.

Let's now investigate fitting a telecompressor candidate to a typical catadioptric system:

First, focus the instrument (without the telecompressor) so that an object at infinity will be focused well to the rear of the lens' proposed location. With catadioptric systems that focus by moving either their primary or secondary mirror, this is simply a matter of adjusting the focusing knob. (One common 8" Schmidt-Cassegrain

can have its infinity focus moved almost 15" outside the telescope in this manner.) In refractors and Newtonians, the focal plane is fixed, which requires you to use another approach that we'll get to in a bit.

Measure the distance from the point where the telecompressor will be inserted (where the cone of light fills its aperture) to the infinity image plane that you moved outside the telescope, and call this distance d_{old} . Then, without changing the focus, insert the telecompressor lens and measure the distance (d_{new}) to the new infinity image plane that forms.

The effective focal length (F_{eff}) of a telescope/ telecompressor combination equals the focal length of the telescope F_t (measured from the primary to the d_{old} image plane), multiplied by the new image plane distance (d_{new}), divided by the old image plane distance (d_{old}), or:

$$F_{eff} = F_t \times d_{new} / d_{old}$$

The image amplification (A) due to the telecompressor equals the new image plane distance (d_{new}), divided by the old image plane distance (d_{old}).

$$A = d_{new} / d_{old}$$

In order for the inserted lens to work as a telecompressor or image reducer, the new infinity image plane must fall between the old image plane and the telecompressor. If this doesn't happen, either the location of the old image plane should be moved farther away from the telescope, or a positive lens with a different focal length should be tried, or both.

The focal (f) number of the

These two photos of M-27 show a common effect of a telecompressor. The shot above was taken with a 14" scope at f/11 (south lies to the left). Photo by Leo Henzl. At right, bringing the f/ratio of a 14-incher down to f/5.5 with a telecompressor can bring on vignetting (south is up). Photo by Bill Iburg.

telescope (without the telecompressor in) is calculated by dividing the diameter of the telescope aperture (D) into the focal length of the telescope (F_t). (Remember, F_t is measured out to d_{old} .)

$$f = F_t / D$$

Adding the telecompressor, which creates a new effective focal length (F_{eff}), will make a new effective focal ratio (f_{eff}) for the system. This can be calculated by:

$$f_{eff} = F_{eff} / D$$

A word of warning about vignetting: A decrease of more than 1.5 to 2 f/stops isn't recommended, because the limited internal size of the telescope's optics will then bring on unavoidable, severe vignetting. Also, with very short effective focal lengths, the image scale (and therefore the size of extended objects) can dwindle to an unusable size. (At some point, small details will get lost in the film grain.)

You can calculate the new f-number (f_n) for the system in two other ways. Which formula you use in your design will depend on the variables you know:

$$f_n = F_t \times d_{new} / d_{old}$$

Since d_{new} / d_{old} equals the amplification factor, this equation can become:

where to get lenses

The following companies sell lenses; write them for a catalog:

C & H Sales Co.
2174 E. Colorado St.
Pasadena, CA 91107

Edmund Scientific Co.
Edscorp Building
Barrington, NJ 08007

A. Jaegers
6915 Merrick Rd.
Lynbrook, NY 11563



$$f_n = F_t A$$

Specifying the Lens

The relations between the focal length of a telecompressor (F_c) and the two infinity image plane distances can be derived from:

$$1/F_L = 1/d_{\text{new}} + 1/d_{\text{old}}$$

Algebraic reshuffling yields the following equivalent equations:

$$F_c = d_{\text{old}} \times d_{\text{new}} / d_{\text{old}} - d_{\text{new}}$$

and:

$$d_{\text{old}} = F_c [(1-A)/A]$$

and:

$$d_{\text{new}} = F_c (1-A)$$

These equations are very handy for planning good telecompressor/telescope combinations. They show that choosing a particular pair of d_{new} and d_{old} distances also uniquely selects the focal length of the telecompressor (F_c) for the system.

Conversely, choosing the amplification factor A and the focal length of the telecompressor uniquely determines distances d_{new} and d_{old} . With these thoughts in mind, let's now examine the Newtonian and refractor systems.

Telecompressing a Newtonian

Since in a Newtonian telescope the infinity focal plane is fixed, there are only two ways to move it outside the telescope comparable to what you can do with a Schmidt-Cassegrain.

The first is to move the primary mirror up the tube closer to the diagonal and install a larger diagonal and bigger diameter eyepiece focuser (to avoid vignetting). The other is to install the diagonal and focuser farther back down the light cone. In both

cases, the increased diagonal size requires installing a larger diameter focuser in the telescope. Once you have done this, the procedure for determining a telecompressor follows the same routine as for a catadioptric.

Focal Reducers

But if you plan to use your telescope/telecompressor combination for photography, there's another way that achieves somewhat the same result with less damage to the telescope tube and your bank account.

In this method, you measure neither d_{old} nor d_{new} : d_{old} is determined by the focal length of the achromat telecompressor, now placed with the convex (crown) element on the side away from the telescope. It has its focal point at the first focus of the Newtonian primary.

The achromat acts as a collimator, or a giant eyepiece, with parallel rays of light emerging from it. You can minimize vignetting by choosing the achromat's focal length, or by fitting a larger diameter focusing tube.

Any camera lens can now image the parallel light beam onto the focal plane — d_{new} depends solely on the focal length of the camera lens. You can get a wide range of f /ratios and effective focal lengths, depending on how varied your camera lenses are. (Bear in mind, though, that the telescope/camera combination will never have a new f /ratio "faster" than that of the camera lens alone — if that lens is faster than the telescope, as most are.) Keep the distance between

the camera lens and the achromat-collimator to a minimum, or again you'll have excessive vignetting.

With a refractor, you'll have to install a shorter tube to allow the infinity focal plane to project far enough out the back of it to allow fitting a telecompressor as described for the Schmidt-Cassegrain. (Be sure to work out your changes on paper before you cut the tube!)

Rich-Field Gadgetry

Lastly, we come to the "visual" telecompressor. At least one manufacturer is selling a simple binocular-objective type achromat as a rich field adaptor — so it's clearly not too difficult to do it yourself. This accessory takes advantage of and utilizes the expanded field of view in a delightful way.

Assume that you have a 2000 mm focal length telescope with a clear aperture of 200 mm, and that you are using a 32 mm ocular with it. The magnification (M) of the instrument equals the focal length of the telescope (F_t) divided by that of the ocular (F_o):

$$M = F_t / F_o$$

or, in this case, $2000/32 = 63x$.

The diameter of the beam of light exiting from the telescope — the exit pupil (EP) — equals the clear diameter of the objective (D) divided by the magnification (M):

$$EP = D/M$$

or, $200/63 = 3.2$ mm.

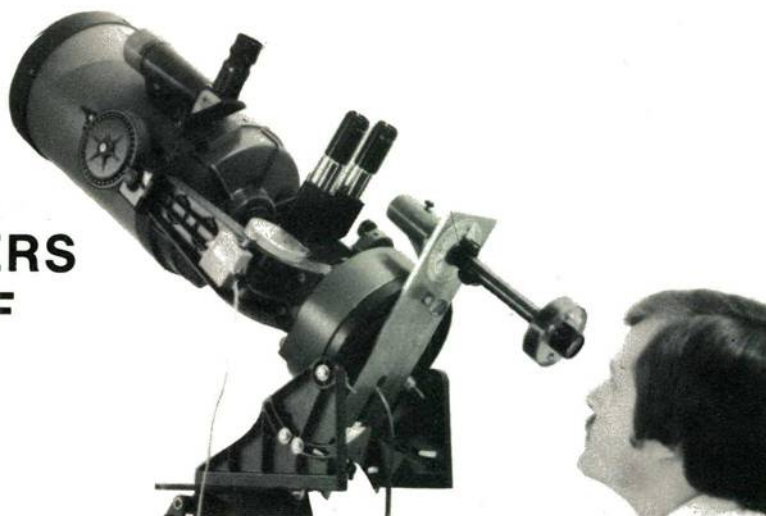
When you install a telecompressor with an amplification factor of one-half, the effective focal length becomes 1000 mm, the magnification 31 power, and the exit pupil diameter increases to 6.5 mm.

Since a completely dark adapted eye's pupil is about 7 mm in diameter, this larger exit beam is still used fully. While still not at the lowest theoretical magnification — richest field limit — a 7 mm exit pupil, your instrument has just become a "very-much-richer-field" telescope.

This lets your eye collect nearly as much light as it can theoretically accept, and thereby gives you the brightest view theoretically possible for that aperture. You are trading off magnification for a substantial improvement in view when you do this, but visually, it's an impressive image. One properly chosen telecompressor could effectively double the number of eyepieces available to you — at a fraction of the cost of a new set!

Steve Greenberg has been an observer and astrophotographer off and on for more than 20 years; he runs a company, called Moonshadow Expeditions, that conducts eclipse tours. He lives in Menlo Park, California.

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observing peculiar galaxies

by
Alan Goldstein

Observing a galaxy is always an exciting experience. You know that the diffuse glow in your eyepiece comes from the combined light of billions of stars organized in a vast cosmic system so distant that its gleam takes millions of years to reach your telescope. Most telescopic observers have examined at least a few galaxies, and those with larger apertures have probably ventured beyond the confines of the Messier list to observe some of the thousands of galaxies listed in the *New General Catalogue* (see "Observing Galaxies" in *ASTRONOMY*, April 1980).

But if you find yourself itching for still more cosmic exploration, why not search out a few of the more unusual denizens of our universe: the peculiar galaxies? It has been said that all galaxies are peculiar to some extent, but here we are talking about the truly strange or distorted galaxies — those officially classified as "peculiar."

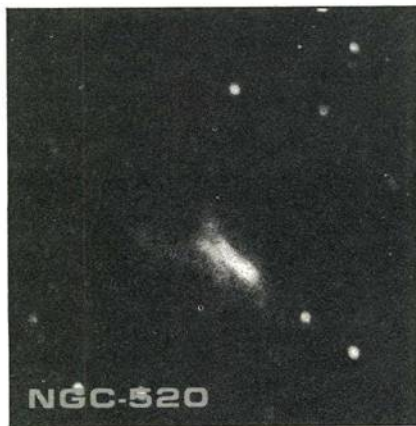
What Makes a Galaxy Peculiar?

Spiral galaxies appear to be the most numerous readily observable type of galaxy, with the ellipticals coming in a rather distant second. Although dwarf spheroidal galaxies — like the Sculptor and Fornax Dwarfs — are the most common in the universe as a whole, they are not observable beyond the Local Group. Irregular galaxies make up only three to four percent of known galaxies, and the peculiar galaxies come in at less than one percent. Of course, galaxies that have peculiarities are more common — such as M-87, the supergiant elliptical whose famous jet gives it a "p" for "peculiar" in its classification: E0p.

There are a number of things which can give galaxies the distinction of being peculiar — such as:

- strange shapes
- strange halos
- rings
- plumes and tails
- unusual dark lanes

- unusual placement of HII regions
- excessively bright or peculiar nuclei
- apparent explosions
- particularly distorted interactions with other galaxies
- possible interactions with intergalactic clouds of dust or gas.



Some of these — like the last — are extremely rare, but examples of each sort have been observed. And even though all peculiar galaxies are relatively rare, there are quite a few in the Messier catalog. M-49 is not generally listed as being peculiar in any way, but it does have a very faint bridge linking it with a tiny irregular galaxy estimated to be about 17th magnitude. M-51's companion, NGC-5195, is a very dusty peculiar galaxy. M-64 has an out-of-place dark patch giving it its title of the "Black-eye Galaxy." M-66 is a barred spiral with somewhat asymmetric arms, and M-77 is a Seyfert-type galaxy with a brilliant nucleus which seems to be exploding. M-101 has very asymmetric arms, as does M-106. The exploding M-82 with its knotty structure is probably the most famous peculiar galaxy.

Except for the case of galaxies which

are obviously involved in a gravitational interaction, the causes of most galactic peculiarities are quite mysterious. For instance, astronomers can't yet explain why some galaxies seem to be exploding. The same can be said about distorted halos, strange dust lanes, and tails and plumes in seemingly non-interacting galaxies.

Most rich clusters of galaxies have their share of peculiar galaxies. Some are "in the thick of the action," where relatively recent interactions with several galaxies may well have caused their present peculiarity, but others are isolated outlying members of the cluster.

Sometimes an explanation is found after intensive study. An excellent example of this is NGC-520, a 13th magnitude galaxy in Pisces with two tails and a heavy central dust lane. Only within the past few years has its "true" nature come to light. The most recent studies imply that this bizarre galaxy is actually two galaxies, both dusty spirals (like M-64 or M-90), in the process of colliding.

Since practically every type of galaxy has a peculiar counterpart somewhere else in the universe, it isn't surprising that a wide variety of peculiarities can occur in any given class of galaxies. While most deep-sky observers know about the jet in M-87, they may not have heard of the four jets shooting out of the barred spiral NGC-1097. This discovery adds the small "p" designation to that galaxy's classification. One jet actually cuts a spiral arm, which in short-exposure photographs can be seen to have "slipped" out of line with the rest of the arm!

What Can You See?

Except for some of the brighter peculiar galaxies, most of these objects lack real beauty unless they are currently involved with other galaxies. And since most peculiar galaxies are fainter than 13th magnitude, you will

need a large aperture to observe them at all. Still, the mere observation of the target galaxy is often enough for even the most experienced observers. The fact that you have observed a galaxy you know is a celestial oddball can be quite satisfying in itself, and actually seeing the feature which makes the galaxy peculiar is just "icing on the cake."

The techniques involved in observing peculiar galaxies depend on the type of peculiarity the particular galaxy has. If the galaxy is a face-on spiral, it will be difficult to observe because you are looking through the thin plane of the galaxy. If it is inclined more to our line of sight, it will be easier to observe. The detection of dark lanes is easier than detecting bright areas, unless the bright areas are very bright.



So let's be honest: Observing the peculiar features visually is generally difficult to impossible. The extended halos which give certain galaxies their peculiar designation require a very large aperture to be observed with any degree of certainty. Extensions, such as tails, are usually too low in surface brightness to be seen with any amateur instrument. Irregular galaxies are generally so thin and diffuse that they are hard to see, so unless the peculiar irregular is bright, you'll be lucky to see the galaxy at all — much less its peculiarity.

Turning to somewhat more visible features, strange or asymmetric arm structures can sometimes be seen as an uneven hazy patch. If dark patches are large or broad enough, they might be visible in moderate-size telescopes. But bright HII regions have to be of immense size in order to be observable, so you can safely assume that you won't be able to see most extragalactic HII regions individually. As a chain or large clump, though, these regions of ionized hydrogen will make the glow of the galaxy brighter in that particular area. Explosive galaxies — like the Seyferts — reveal a bright

peculiar galaxies

NGC #	R.A.(1981)Dec.	Mag.	Description
7828/9	0h00.8m +62°55'	14	Sb interacting w/intergalactic cloud?
14	0 07.7 +15°41'	13½	Bean-shaped
128	0 28.3 +02°45'	13	Square central hub (Type SO)
145	0 30.8 -05°16'	12	Highly asymmetric SBb
191	0 38.0 -09°07'	12	Very distorted disk, due to interaction S(B)b
274/5	0 50.1 -07°10'	13/13½	Very peculiar, distorted interacting pair
520	1 23.6 +03°42'	13	Very dusty, with dark lane & 2 tails
523	1 24.2 +33°56'	13½	Shoe-shaped, very knotty
772	1 58.3 +18°55'	11½	Strangely placed bright arm
985	2 33.6 -08°51'	14	Ring with Seyfert nucleus
1097	2 45.7 -30°22'	10½	SBb with jets
1144	2 53.3 -00°16'	13	Heavily distorted Sc, looped arm
1316	3 21.8 -37°19'	10½	SO pec. with dust lane
1569	4 29.1 +64°48'	12½	Irregular with dust patch
1961	5 40.1 +69°22'	11½	Sb pec., largest spiral, irregular arms
2276	7 21.0 +85°47'	12½	Sbc with very asymmetric arms, interacting
2445	7 45.6 +39°03'	13	Heavily distorted peculiar, almost a ring
2537	8 11.9 +46°03'	12½	Very strange, circular, neither spiral nor irregular
2633	8 46.1 +74°11'	12½	SBb, strange HII regions on north
2685	8 54.2 +58°49'	12	SO type surround by HII region, like a cocoon
2782	9 12.9 +40°12'	12½	Strange spiral, arm to cloud
2992/3	9 44.8 -14°16'	13/13½	Pec. Sas with tails, near QSO Weedman 2
M-82	9 54.3 +69°46'	9½	Cigar-shaped, very knotty
3310	10 37.7 +53°36'	11½	Irregular with outer loop
3414	10 50.2 +28°04'	12	Elliptical with 2 counter-jets
3432	10 51.4 +36°43'	12½	Irregular or edge-on spiral with possible tail
3445	10 53.5 +57°05'	13	Roundish irregular with tail
3448	10 53.5 +54°25'	12½	Semi-rectangular, dusty with 2 tails
3656	11 22.6 +53°57'	13½	Circ., very dusty w/disturb. outer lenses & loop south
3664	11 23.5 +03°26'	13	Irregular SB with 1 arm
3690	11 27.4 +58°40'	12½	Distorted SB with very strange companion
3718	11 31.5 +53°11'	11½	SO with dark lane arching over nucleus
3729	11 32.8 +53°14'	13	Peculiar with outer ring and a jet
3981	11 55.3 -19°47'	12½	SBb nearly edge-on, distorted halo
4027	11 58.6 -19°09'	12	Hook-shaped
4038/9	12 00.9 -18°45'	10½	Ring-tail, a spectacular peculiar
4088	12 04.6 +50°39'	11½	Sb with distorted arms
4194	12 13.2 +54°38'	13	Very strange, mushroom-shaped
4438	12 27.1 +13°05'	11	Sb spiral with distorted arms, edge-on/tail
4618	12 40.6 +41°16'	11½	Hook-shaped, one armed spiral w/pec. companion
4651	12 42.5 +59°04'	12	Sb spiral w/faint tail leading nowhere
4747	12 50.8 +25°53'	12½	Very dusty edge-on disk
4861	12 58.2 +34°58'	12½	Irregular w/large bright HII region at so.
5128	13 24.2 -42°55'	7½	Elliptical (?) with dark lane & jets
5195	13 29.3 +47°22'	11½	Companion to M-51, very dusty
5218	13 31.6 +62°51'	13	Pec. SBb w/folded arms & thin bridge south to NGC-5216
5253	13 38.8 -31°33'	11	Pec., M-82 type
M-101	14 02.6 +54°27'	8.5	Sc with asymmetric arms
5614	14 23.4 +34°56'	13	Sb with tail
5665	14 31.5 +08°09'	13	Compact spiral, very knotty w/cE, distorted
5996	15 46.1 +17°56'	13	Highly distorted, thick-armed SBb
6621/2	18 13.1 +68°20'	13½	Distorted SBb & irregular with tail, in contact
7252	22 19.7 -24°46'	13	SO with 3 loops and a tail
7284/5	23 17.0 -24°57'	13/13½	SBb with E4 at the end of an arm
7625	23 19.6 -04°46'	13	SO with distorted halo
7678	23 27.5 +22°19'	13	Sbc w/thick southern arm
7714	23 35.3 +02°03'	13	Distorted SBb w/looped arm & tails
7727	23 38.9 -12°24'	11½	Lenticular with distorted halo
7757	23 47.8 +04°04'	12	Sb w/pec. chain of HII regions



stellar nucleus, and given sufficient aperture, they are among the easiest peculiar features to observe.

Once you have the urge to look for specific peculiarities, the real challenge begins. Is the sky dark and clear enough? Do you have sufficient aperture? Looking for these features might be considered the "ultimate quest" for the serious galaxy observer, but for many these challenges are worth the time and effort.



Challenging the Peculiars

NGC-4038/9 is the famous "Ring-tail Galaxy." A very peculiar galaxy indeed, some astronomers consider it an interacting pair of spirals, while others theorize that we are actually seeing a galaxy in the process of splitting in two! The Ring-tail is very bright, and its strange "U" shape is visible in even a 6-inch telescope. This impressive object lies very near NGC-4027, a slightly fainter peculiar galaxy shaped like a hook.

NGC-1961 has recently been identified as the largest known spiral galaxy in the universe, containing some 2 trillion stars in a galaxy 600,000 light-years across. It is also unusual in having a highly asymmetric spiral structure, as if it had interacted with another galaxy, but there are none around. Since the arms are too low in surface brightness to be seen in a 21-inch telescope, their structure seems

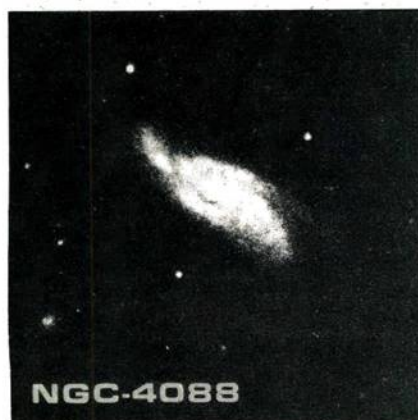
to be beyond the capability of amateur instruments. But just seeing this cosmic giant is sufficiently appealing.

NGC-3718/29 are a pair of peculiar galaxies found in the same field, both bright enough to be seen with an 8-inch aperture. Whether their peculiarities are caused by a mutual interaction is uncertain, but they don't appear to be. NGC-3718 has a strangely placed dark lane, which may be visible in moderate-size telescopes. It seems to be arching over the nucleus. NGC-3729's two peculiarities — an outer ring and a jet — are beyond the reach of amateur telescopes. Still, it's interesting to find more than one peculiar galaxy in the same field of view.

NGC-5195 is the peculiar companion to the most famous interacting galaxy, M-51. It is a small, dusty, and very dense star-city. Visually, this galaxy is bright enough to be seen through small aperture instruments as a roundish patch with a brighter center. With moderately large telescopes, NGC-5195 reveals a bright stellar nucleus. For a challenge, try to see all of the bridge connecting M-51 and NGC-5195.

NGC-4861 is an irregular galaxy that contains a semi-nuclear region and a very large emission nebula off to one side. This nebula is rather small and very concentrated. When I first observed this galaxy, I carefully sketched it, unaware of the type of galaxy or peculiarity I was seeing. As it turned out, the sketch made with an 8-inch under excellent skies revealed the nebula as a faint star. Such large HII regions seen at great distances appear nearly stellar.

NGC-5128, also known as Centaurus A, is a bright galaxy which appears as an elliptical with a large dark lane cutting across it. At -43° , this galaxy is not favorably placed for observation from the northern United States. With a magnitude of $7\frac{1}{2}$, it would be one of the most spectacular sights in a small telescope from a southern hemisphere location. If you do observe this galaxy, remember that you are looking at the



nearest of all double-lobed radio sources, and if your eyes could see radio waves, Centaurus A would appear truly immense, with giant lobes spreading out of the eyepiece field on both sides.

M-101 is another of the peculiar Messier galaxies. The arms of this Sc spiral are fairly asymmetric, but for no apparent reason. There are a number of dwarf galaxies in the area, but they just don't seem large enough to cause the observed distortion. This galaxy is more difficult to see than its magnitude of $8\frac{1}{2}$ would lead you to believe, because it is face-on to us and has a rather low surface brightness. With moderate-size instruments it appears as a huge roundish patch, but the arms can be glimpsed in large telescopes.



NGC-7727 is one of the brightest galaxies in Aquarius, but its peculiarity is structural. The region of the disk/halo border is strangely shaped, and no one knows why. In this case (as in many others), the interest in observing the object is our knowledge of its mysterious strangeness, since the peculiarities are too faint to see. What sorts of things are going on out there?

Peculiar galaxies may often lack some of the visual excitement of better-known objects, but occasionally they will surprise you by revealing their strangeness. And whether they appear strange through the eyepiece or not, we know that when we observe a peculiar, we are looking at one of the frontiers of modern astronomy. The challenge is there — will you accept it?

Alan Goldstein is an amateur astronomer and the founder and National Coordinator of the National Deep Sky Observer's Society (NDSOS). For information on the NDSOS, send a stamped, self-addressed envelope to NDSOS, 3430 Bryan Way, Louisville, KY 40220.

Photos by K.A. Brownlee with a 16" telescope.

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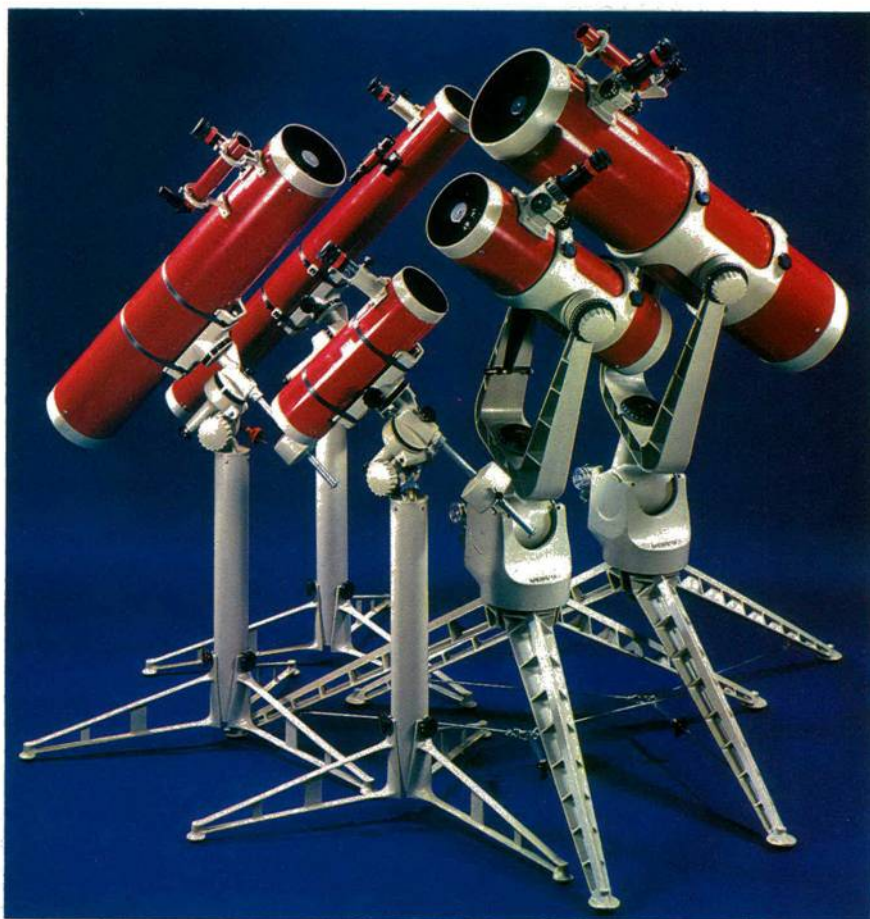
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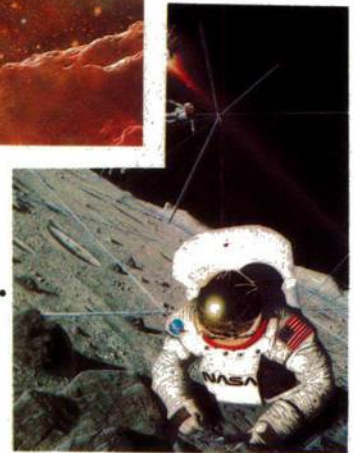
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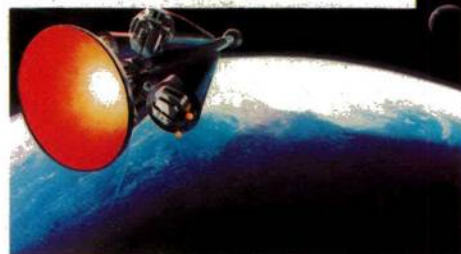
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AstroNews

McDonald Plans 300-inch Telescope

At its opening in 1939, McDonald Observatory, located in west Texas, had the second largest telescope in the world — an 82-inch reflector. When the new 107-inch reflector was dedicated in 1969, it was likewise pre-eminent as the world's third largest. And if all goes according to plan, McDonald may soon have the edge on everyone — in December the University of Texas (UT) endorsed McDonald's plans to build a 300-inch (7.6-meter) reflecting telescope, the largest in the world.

The McDonald announcement is full of superlatives. The estimated cost of the mammoth facility will be \$40 million (in contrast, the original observatory was built with an initial bequest of \$800,000). The proposed telescope will have more than double the light-gathering capacity of the 200-inch reflector atop Mt. Palomar, the reigning monarch of astronomy for more than 30 years. It will also all but eclipse the huge 236-inch Soviet reflector in the Caucasus, currently the world's largest but with a miasma of technical problems that have all but compromised its scientific value.

But perhaps the greatest breakthrough in the new McDonald telescope will be its innovative design, not its size. Largest in a new generation of ultra-light and ultra-sophisticated telescopes, the McDonald instrument will employ a mirror weighing a relatively light 10 tons. The thickness of the primary will be only about four inches rather than the four feet expected on the basis of classical design. Such savings are made possible only by use of the computer — first in the original design and again in the support structure itself, which will consist of a series of "push-pull" modules controlled by a computer to keep the mirror surface in a perfectly parabolic shape as it undergoes the various stresses of movement and its own ponderous weight.

In addition, the new

instrument will employ an altitude-azimuth mounting, allowing a much-scaled-down "dome" to house it, with the entire structure (rather than just the telescope) moving with the Earth's rotation. Again, a computer acts as a guide, tracking the stars with pinpoint accuracy. With a host of modern electronic instruments — none of which have to be mounted directly on the scope — it is safe to say that the 300-inch telescope will have a range of observation and precision never dreamed of in the past.

"We're excited about the project," concedes Dr. Harlan Smith, director of the observatory. "Astronomy has unraveled a lot of mysteries about the evolution of stars nearby. Now we want to extend that process out to the galaxies. To do that, we need a telescope more powerful than any now in existence."

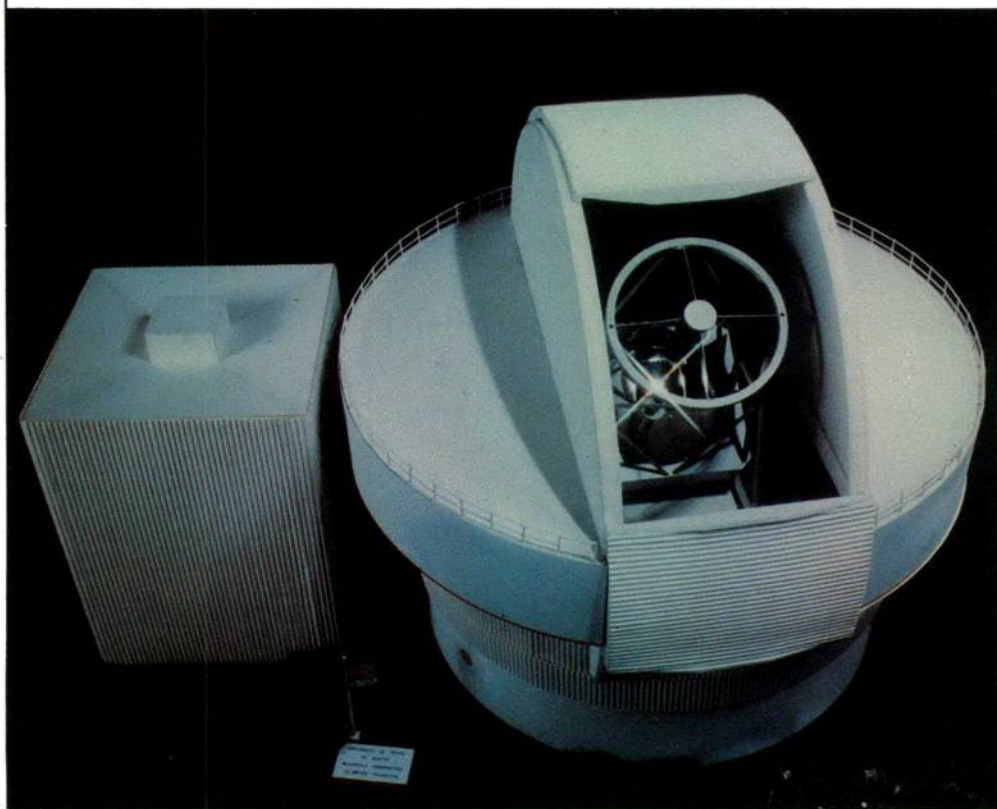
Initially, the 82-inch reflector was dedicated to understanding "the evolution of stars." Indeed, it saw its most noted successes in stellar spectroscopy and photometry, both critical to understanding stellar life histories. But its now-modest mirror cannot hope to gather enough light to peer into the realm at the frontiers of modern astronomy — the gap between the farthest visible dim galaxies and the awesome "edge" of the universe where such incomprehensible phenomena as the quasars seem to occur.

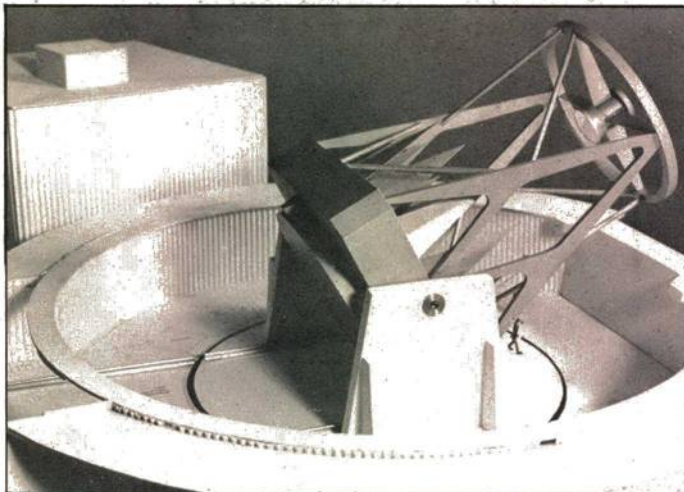
"It is this gap that contains galaxies that were born when the universe was near its beginning," says Dr. Tom Barnes, research astronomer at UT and Smith's assistant. "The quasars were formed when the universe was very young. Now, like the dinosaurs, they've 'died out'

— we're seeing them as they were perhaps 10 billion years ago. Ironically, we know more about the first five minutes of the universe than about the period from then up to five billion years. Now it's time to come back in a little closer and fill in the missing information."

The new "Texas Telescope," as the University calls it, will be in an excellent position to do just that. Because of its remote location in the Davis Mountains of West Texas, McDonald has been one of the few major observing sites in North America to remain virtually unaffected by light pollution and smog. The atmosphere has an idyllic, monotonous clarity almost the whole year long, and from the 6800-foot perch of McDonald the desert seems to sweep out almost to infinity. And because of the southerly latitude, astronomers can see

McDonald Observatory's proposed 300-inch "Texas Telescope," seen in these architectural models below and at right, would be the world's largest optical instrument. Photos courtesy of the McDonald Observatory, University of Texas.





not only all of the northern sky from McDonald, but also more of the southern heavens than from any other of the major North American observatories. No one, at least in Texas astronomical circles, is arguing

with Smith's cautious optimism: "McDonald has certainly been one of the world's outstanding observatories. Now, with the 300-inch, I think it could, at least for a time, become the world's greatest."

Evidence for Neutrino Mass

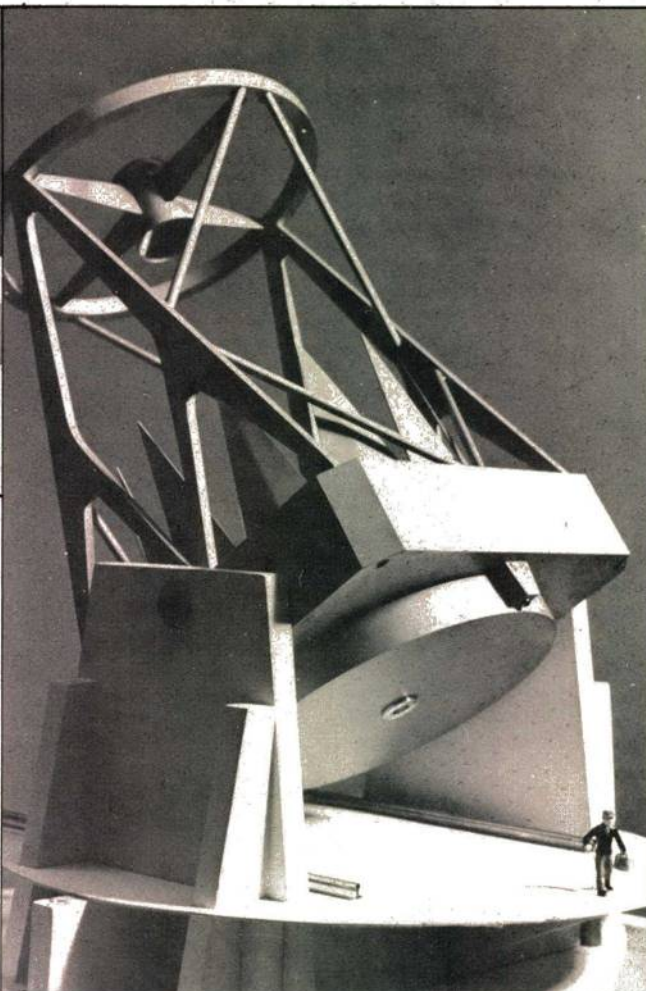
Neutrinos are weird subatomic particles which have long been thought to be lacking both mass and charge. Traveling at the speed of light, neutrinos interact with matter so weakly that one could traverse a slab of lead light-years thick and emerge unchanged, like a photon passing through a thin window.

Notoriously hard to detect, scientists have nevertheless identified three types of neutrinos which, together with three charged leptons (including the electron) and the various quarks, they believe constitute the most fundamental particles in nature.

Now, however, it appears that neutrinos may not be massless after all. If this is true, the consequences for

astrophysics and cosmology are immense.

One calculation of the Big Bang theory implies that there are roughly a billion neutrinos for every proton in the universe. There are so many neutrinos that they would make up the bulk of the mass of the universe and account for the mysterious "missing mass" in large clusters of galaxies. And if most of the mass of the universe is in fact locked up in the form of the ghostly neutrinos, there could be enough total mass to "close" the universe. The exact determination of the masses of all three types of neutrinos will enable astrophysicists, using the general theory of relativity, to deduce whether the universe will keep on expanding forever or will eventually



collapse, possibly producing a new Big Bang.

Furthermore, if neutrinos do have mass, the gravitation of our Galaxy may have trapped a spherical "halo" of neutrinos which were created in the first moments of the Big Bang, and some of these would be decaying all the time. It might be possible to detect these decays. It is this fact which led a scientist at NASA's Goddard Space Flight Center to look for new evidence of neutrino mass.

Dr. Floyd W. Stecker, of Goddard's Laboratory for High Energy Astrophysics, proposes that there may be definite astronomical evidence on the neutrino mass question. He has followed up on a recent suggestion by CERN (Centre Europeen de Recherche Nucleaire) physicist A. de Rújula and Nobel Laureate Sheldon Glashow of Harvard that evidence for neutrino decay might be found in ultraviolet astronomical observations.

Stecker, writing in the October 27 issue of *Physical Review Letters*, concludes that tentative evidence of a

spectral line, which may be from decaying neutrinos, exists near the ultraviolet wavelength of $1700 \text{ \AA}$ in various rocket observations.

Ultraviolet astronomical observations can only be done above the Earth's atmosphere, with rockets and satellites. Stecker used rocket observations by Dr. Richard Henry of Johns Hopkins University and his collaborators as well as observations of a French group working with data from the French D2-B spacecraft. Future ultraviolet astronomy studies, providing more refined observations, are needed in order to further test the neutrino-decay hypothesis.

The strength of emission lines from ultraviolet spectroscopy can provide important data on the rate of decay, which is related to the half-life of the neutrino. Stecker believes that if his interpretation of the ultraviolet data is correct, neutrinos live so long that only one neutrino in 10 million has decayed since the universe began in the Big Bang.

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If Stecker's conjecture is correct, the "heavy" neutrinos which produce this spectral line at the observed wavelength would still weigh so little that it would take a billion of them to equal the weight of one nitrogen atom, and a single one would weigh far less than an electron — currently the lightest known particle with mass.

Stecker's mass estimates agree with recent reports by a group at the Institute for

Theoretical and Experimental Physics in Moscow. Other recent evidence for neutrinos having mass has been reported by a group at the University of California at Irvine under Dr. Frederick Reines.

The neutrino mass question is so significant that a number of experiments are currently being conducted around the world to settle the issue beyond doubt and accurately measure the mass.

Flying Rubble

Asteroids, the long-neglected munchkins of the solar system, are rapidly becoming a hot astronomical topic. This was clear at last fall's meeting of the American Astronomical Society's Division for Planetary Sciences (DPS), held in Tucson, Arizona, where a number of papers on asteroids were presented.

What seemed like an off-beat idea only a few years ago — that some asteroids are

actually binary or even multiple systems of bodies — is supported by a growing body of observational evidence. In a paper presented at the DPS meeting, Clark Chapman, Donald Davis, and Stuart Weidenschilling of the Planetary Science Institute in Tucson reported that their theoretical calculations indicated that collisions among asteroids may be far more common than has been

thought. Such collisions could shatter large asteroids into two or more fragments, which could remain gravitationally bound to each other as flying rubble piles or disrupted into a double or multiple orbiting system. "The problem is whether they can become binaries before they're destroyed entirely," according to Clark Chapman.

Alternatively, the researchers pointed out that a collision could cause an asteroidal body to "spin up," rotating so fast that it would become unstable and split into fragments, which again could remain gravitationally bound. Of course, such multiple asteroids would themselves be subject to subsequent collisions, which would probably destroy the system as a bound unit, but such losses would be balanced by the formation of new multiple systems. Thus a "steady-state population" of such systems would be expected, with newly-formed multiple asteroids replacing those which had been disrupted.

Other strange asteroids, such as Hektor and Kleopatra, could be formed by low-velocity collisions resulting in the two bodies sticking together. (See "Hektor: A Strange Asteroid" in *ASTRONOMY*, March 1979 and "Hektor is a Strange Asteroid" in *AstroNews*, *ASTRONOMY*, May 1980.)

On the basis of their model, Chapman said, "We think there must be more than 1% binary asteroids and as many as 10% in the steady state population."

In another paper presented at the DPS meeting, a group of researchers from Steward Observatory and the Sacramento Peak Observatory

reported on their examination of asteroids for possible secondary bodies using the technique of speckle interferometry. This technique averages a large number of very short observations of an object to eliminate extraneous "noise," such as that produced by the passage of light through Earth's unstable atmosphere. This allows resolution of objects too close to be resolved by ordinary means. "We started out to test our system," the researchers said, "and now the results look interesting for asteroids." Thus they conclude that speckle interferometry can be a powerful tool for the study of asteroidal binaries.

The researchers reported that their measurements of Pallas and Victoria show evidence of secondary objects. The preliminary results indicate that both asteroids have "satellites" in close, and possibly synchronous, orbits. The Pallas secondary is estimated to be about four magnitudes fainter than Pallas itself, in an orbit 2.7 Pallas radii distant. Victoria, about 120 km in diameter, has a secondary about 3 Victoria radii (180 km) distant.

Other asteroid reports at the DPS meeting indicated that Ceres is "round as a basketball," Juno is a slightly elongated 290 x 245 km, and Vesta shows interesting variations although it's basically round. Detailed occultation measurements of Juno showed real limb irregularities up to eight kilometers. No secondary occultations, which would imply the presence of a satellite, were reported, but such a finding does not rule out the possibility of Juno being a multiple body.

Building in Space



Using beams spun out of spools of flat aluminum by an automated beam builder (a mockup of which is seen at right), space-suited engineer Stephen Hall assembles a triangular prism in "weightless" conditions underwater. Someday astronauts may use such a beam machine carried aboard the Space Shuttle to assemble large structures (such as a giant radio telescope) in orbit. In this test at NASA's Marshall Space Flight Center in Huntsville, Alabama, Hall is taking beams from the simulated machine located in a Shuttle cargo bay mockup and assembling them outside the bay. It is one of many tests being conducted in Marshall's 1.3 million gallon Neutral Buoyancy Simulator to explore space construction technology. NASA photograph.

Solar Investigators

Scientists from around the world met last November at the Goddard Space Flight Center in Greenbelt, MD, to discuss their findings on the solar constant, a measure of the energy output of the Sun.

The solar constant is important because its precise value helps scientists in understanding the Sun's physical processes and because even the smallest long-term change can affect our climate and many other factors governing life on Earth.

Dr. David G. Murcray of the University of Denver reported

on studies which used a thermopile unit in a 1,000-pound balloon payload flown several times in 1967-68, and then again in 1978-80. Because balloons fly in the Earth's atmosphere, it is often thought that ozone and perhaps nitrogen at these altitudes distort observations of the solar constant. Even after taking these factors into account, however, the data indicated a real increase in the solar constant of 0.4%.

Dr. C. Frohlich of the Physico-Meteorological Observatory, World Meteorological Center, in



A short-term variability in the total energy output of the Sun has been recently detected. In this H-alpha photograph, a prominence erupts from the active solar surface. Photo by Edwin Hirsch.

Davos, Switzerland, reported on balloon flight measurements made in June of 1979 and again in 1980. The results from a solar constant device known as the PMO-6 agreed almost completely with those from NASA Aerobee sounding rocket flights and the Solar Maximum Mission (SMM) spacecraft, and on a relative basis with those of Nimbus 6 and 7. These measurements showed that the solar constant was stable over the long term (years) but varied within a few tenths of a percent in the short term (days).

Charles H. Duncan of Goddard reported on sounding rocket studies which were conducted when the Earth Radiation Budget instrument on Nimbus 6 started showing readings about 1.5% higher than expected. During the ground testing of the sounding rocket radiometers, some unexpected values appeared. A careful check showed these to be caused by a black gnat in the instrument. The sounding rocket results showed small but significant differences from the Nimbus 6 and SMM findings.

Mr. J. M. Kendall, Sr., of the Jet Propulsion Laboratory (JPL) in Pasadena, CA, reported on results achieved with a device known as a PACRAD, or Primary Absolute Cavity Radiometer, flown on a sounding rocket. PACRAD was especially designed to compensate for the conditions experienced during the change from the Earth's atmosphere to the hard vacuum of space. Demonstrating the effectiveness of this feature, its readings went up to a peak as the rocket ascended, and held constant while locked on the Sun, and then declined

sharply as it lost the Sun. This led to the general conclusion that the PACRAD is a valid instrument for measurement of the Sun's brightness. Its findings generally agreed with the balloon and other findings that the solar constant has increased by about 0.4% in the last decade.

Dr. Richard C. Willson, also of JPL, using data from the Active Cavity Irradiance Monitor of ACRIM on the Solar Maximum Mission spacecraft, reported two comparatively large solar constant decreases in early April (0.2%) and late May (0.1%) of this year. Working with the same data, Dr. Hugh Hudson of the University of California at San Diego found a strong relationship between the behavior of specific solar activity indicators such as sunspots and these dips. In fact, using the data from the first decrease he was able to construct a model which predicted the second dip while the ACRIM data for it were still being processed.

Nimbus 6 and 7 Earth Radiation Budget instrument data showed about 20 dips, at least 16 of which seemed to be unambiguous and to show some correlation with solar activity — they happened within four days of increases in solar activity indicators, such as sunspots.

Elaborate studies have recently been made on the measurement of variations in solar energy output and on our theoretical understanding of their origin.

In terms of actual measurements, detectors have found variations of the solar constant on time scales as short as days. But while variations over a period of years, such as the 0.4% increase in the solar constant over the last decade, have

been reported, they are not yet accepted by all the researchers.

We can also determine variations in the solar constant indirectly by measuring solar

temperature and radius changes. Variations in both values have been reported by some researchers, but these results have also not been accepted by all.

On the theoretical side, it is clear that any change in solar luminosity must be reflected by changes in the size of the Sun, so data on variations of the solar radius are very important. Also significant is the theoretical relationship between changes in solar radius and changes in luminosity.

More detailed work on this problem was presented at the conference, and it appears that the relationship depends on the physical mechanism that produces it. Understanding the underlying mechanism is important, since it is the only way we can determine the history of solar luminosity changes and project their future.

Radio Supernovae

So far only two supernova remnants have been found that produce radio waves at a very young age of about a year. Both are in other galaxies. The most recent one was discovered as a radio source last year by University of Minnesota radio astronomer J.M. van der Hulst and his collaborators.

On April 19, 1979, Gus Johnson, an amateur astronomer in Swanton, Maryland, first discovered the optical supernova SN 1979C in the spiral galaxy M-100 (NGC-4321). It reached a peak of 11th magnitude shortly after discovery.

Van der Hulst and his colleagues used the new Very Large Array (VLA) in New Mexico to map M-100 in 1979. At that time they detected no radio emission from the supernova down to a very low intensity level of about 0.0002 jansky.

In the next year the optical supernova faded from view. But on the suspicion that the

radio emission might appear later than the optical, the astronomers again mapped M-100 with the VLA in 1980. The supernova then appeared as the strongest source in the field, with an intensity of 0.005 jansky.

Previous to this discovery, the strongest source in the radio sky at centimeter wavelength was Cassiopeia A. This radio source is associated with a supernova remnant 300 years old and is about 10,000 light-years away. Most supernovae do not emit a significant amount of radio radiation until they are about 50 to 100 years old.

The M-100 supernova is about 200 times stronger than the much older and nearer Cassiopeia A, and in August of 1980 became even stronger by about 50 per cent.

The astronomers expect the new radio supernova to fade gradually over the next one to two years and then disappear entirely, because of its great distance.

Lick Licks Light Pollution

Is the fight against light pollution a losing battle for astronomers — especially in a fast-growing metropolitan area? The staff of Lick Observatory is now happily saying, "No!"

In 1977, Lick's future looked dim, indeed — or rather, not dim enough. The city council

of nearby San Jose was about to approve the replacement of their existing mercury vapor streetlights with more efficient high-pressure sodium (HPS) lamps. The brightness of the sky at Mount Hamilton was already 2½ to 4 times that of a natural dark sky because of San Jose's light, and with

AstroNews

HPS lighting and San Jose's rapid growth rate, that figure could have increased in ten years to nearly six times. What's worse, HPS emissions extend over a much broader part of the spectrum than mercury vapor.

What exactly did Lick stand to lose? Staff astronomer Sandra Faber points out that the light from a typical quasar reaching Earth is only 2×10^{-17} of that produced by one ordinary streetlight. If the quasar's light and that of the streetlight are at different wavelengths, the latter can be quite effectively subtracted out by computer. This is how Lick has managed to continue doing excellent research, since mercury vapor lamps only emit at a few narrow spectral lines.

High-pressure sodium lights, however, are a different matter. Like their cousins, low-pressure sodium (LPS) lamps, they have one very strong emission band (the sodium D-lines) in the

visible spectrum (yellow), and another in the infrared. But HPS lamps have in addition a continuum between these bands. They thus cause interference all the way from the yellow through the red and into the infrared — exactly where research at the frontiers of astronomy is being done. As Dr. Faber notes, "The red in general is a very important spectral region, because you look at distant galaxies there. The most prominent feature that people will be looking for is H and K (a pair of bright calcium lines), which turns up at 4000 Angstroms. In distant galaxies, that's redshifted to 8000 Å, and that's right around where the HPS lamps are putting out a lot of stuff." In a low-pressure sodium lamp, however, there is virtually no emission below the D-lines until you get to 8190 Å. (That sodium line is, unfortunately, a good indicator of M-dwarf stars, but the narrower emission band

of LPS means that it could be shifted out from under the local interference. The wide-band blockage of HPS is very difficult to avoid.)

Low-pressure sodium, therefore, was the lighting favored by the astronomers. But they knew that despite Lick's impressive record of scientific accomplishments and the presence on Mount Hamilton of one of the world's largest telescopes, San Jose's leaders would have to choose a lighting system mainly on cost. And according to information gathered by the city's electrical engineering department, HPS was the answer. Dr. Faber and her associates decided to find out for themselves whether that conclusion was correct. The city council agreed to delay their final decision until the Lick astronomers could study the situation.

Almost immediately, they found major flaws in a report from another city that had been given a lot of weight in San Jose's decision. There ensued a series of events including the formation of an *ad hoc* lighting committee, great confusion over cost and effectiveness data from the

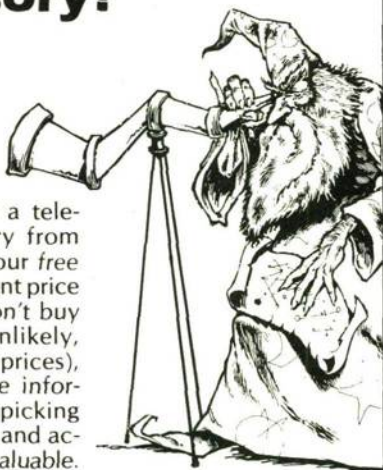
different lamp manufacturers, and a cost comparison — on paper — of HPS and LPS in sample neighborhoods. The comparison heavily favored LPS, but some city officials worried that the public wouldn't like the bright yellow color of LPS as well as the pinkish-yellow of HPS. So the next step was a field test in two neighborhoods, which included Dr. Faber and other volunteers (many from the League of Women Voters) personally talking with all the residents of the test areas. They found no significant difference in public response to the two types of lights. Finally, in mid-1979, a large-scale field test was done, using 1000 lamps each of HPS and LPS. When the data were analyzed, they again showed an economic advantage to LPS.

The final plan adopted by the city council calls for the use of some HPS lamps on certain arterial streets, but the areas of San Jose nearest Lick will have LPS. The changeover will be completed by 1982. And San Jose is currently drafting an ordinance to control wasteful lighting by private commercial concerns.

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He called it "The Case of the Missing Sunspots" when he began his investigation of the three-hundred-year-old mystery. The clues were cold, buried in musty old astronomical journals left by his professional predecessors. Still, astronomer John Eddy felt confident that he could explain away the strange observations of these men, observations that did not fit our concept of a regular and constant Sun. He failed.

The evidence pointed in another direction. What ancient man had feared most and tried to forestall through myriad Sun-centered religions, John Eddy established as fact. The Sun, our source of life, is in fact a variable star and that variability is now being linked to significant historical changes in climate.

The Mystery

For centuries, in infrequent but persistent sightings, naked-eye observers noted dark areas on the Sun's surface. In 1610, Galileo's telescope intensified interest in this strange solar phenomenon. By mid-century, however, even the telescopes seldom revealed spots on the Sun. Scientists of the day routinely recorded the absence in their journals. The French astronomer Cassini, for example, noted the following in 1671:

"...it is now about 20 years since astronomers have seen any considerable spots on the Sun, though before that time since the invention of the telescope they have from time to time observed them."

Meanwhile another change was in progress — a subtle change, but one with quite serious consequences for some. The average temperature dropped about one degree Celsius. Mountain glaciers inched forward. London's Thames River began to freeze regularly and winter carnivals entertained the English.

With the passing of years, temperatures gradually returned to normal — and skywatchers again observed the dark blotches on the solar surface. By the time an amateur astronomer discovered that sunspots increase and diminish in regular eleven-year cycles, the two anomalies had faded into oblivion for most. Since the Sun was considered basically constant, the cycle, once verified, was accepted as a regular part of past, present, and future solar behavior. If any thought at all was given to the old journal entries, it was in reference to observational and instrumental error: "After all, there weren't many observers back then... Their instruments were really pretty primitive... Maybe they didn't look at the right times... Probably they missed spots that were there...."

Scientists have found that our Sun is not as perfectly stable and unchanging as it was once believed to be. For example, we know that during a sunspot maximum, intense solar magnetic fields structure the solar corona into streamers visible during an eclipse, but for a long period in the seventeenth century astronomers did not observe such streamers at all. Photo courtesy of the National Center for Atmospheric Research.

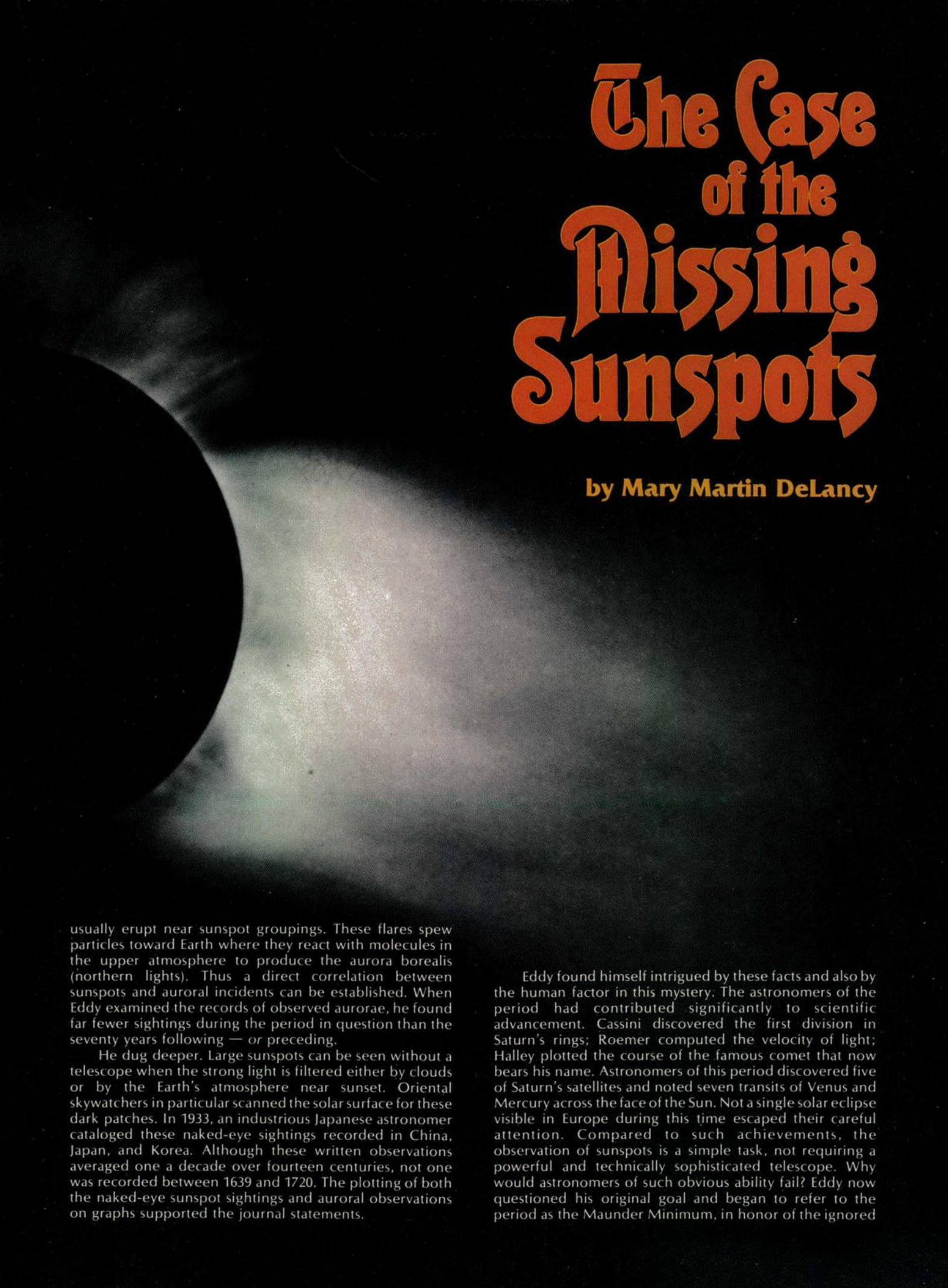
But there were those who studied the records and wondered. In 1894, an English astronomer named Walter Maunder presented a paper to his colleagues titled "A Prolonged Sunspot Minimum" in which he argued unsuccessfully that the Sun *did* behave strangely during the late 17th and early 18th centuries. Thirty years later he again pleaded his case, adding more supporting evidence. No one paid heed.

The Case Is Reopened

Exit Maunder, enter John Eddy some fifty years later. Annoyed by occasional references to the alleged sunspot dearth in relation to the coincident drop in temperature, Eddy determined to find some explanation for the failure of his predecessors to observe and record one of the basic features of our nearest star. Armed with a better understanding of solar physics and recently compiled catalogs of various historical observations, he tackled Maunder's evidence.

"I was sure nothing like a prolonged sunspot minimum had ever happened," Eddy said in a recent interview. "I wanted to clear the records."

Besides the notations directly referring to an absence of sunspots, Maunder had presented recorded auroral sightings as supporting evidence. Solar activity such as flares



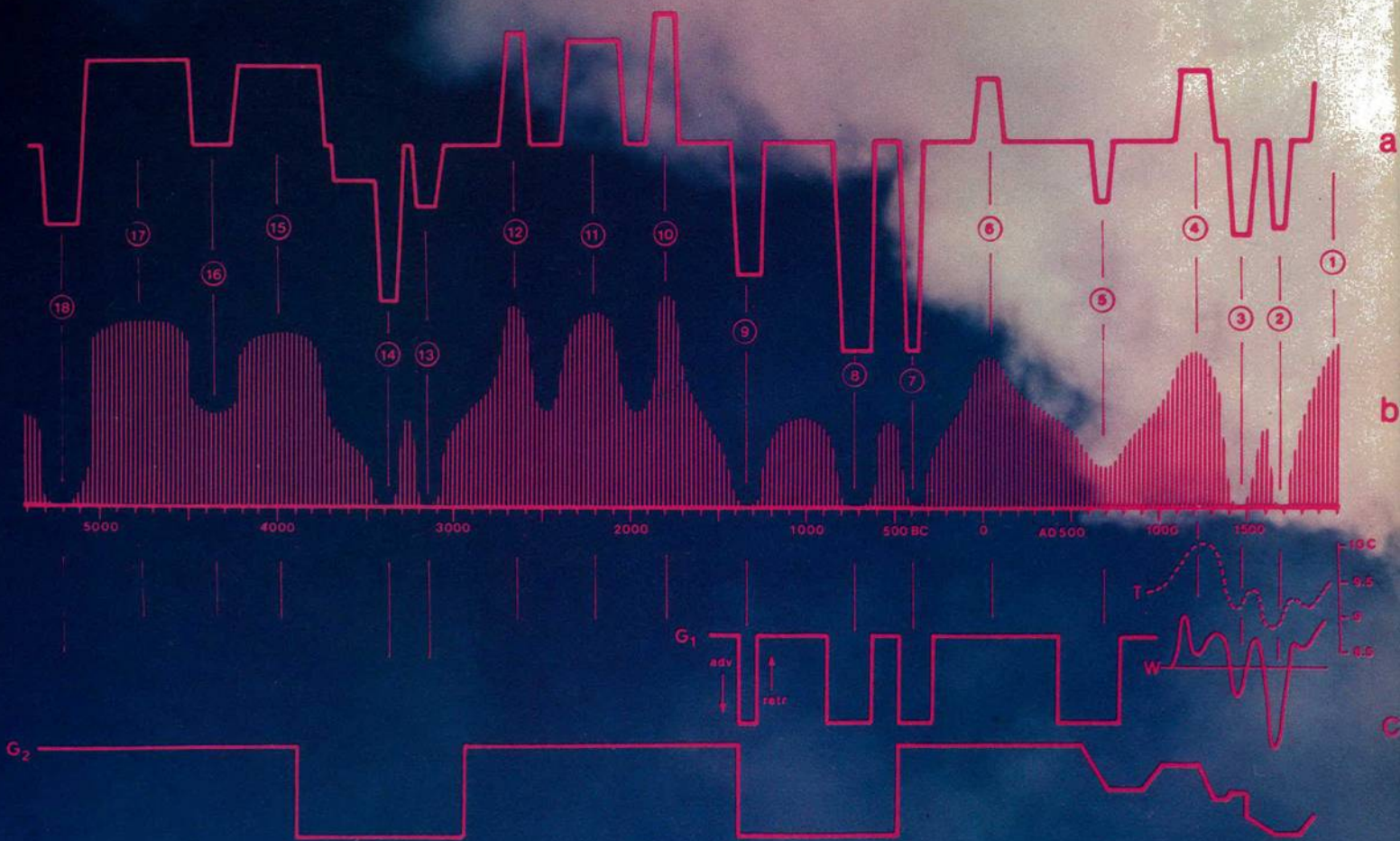
The Case of the Missing Sunspots

by Mary Martin DeLancy

usually erupt near sunspot groupings. These flares spew particles toward Earth where they react with molecules in the upper atmosphere to produce the aurora borealis (northern lights). Thus a direct correlation between sunspots and auroral incidents can be established. When Eddy examined the records of observed aurorae, he found far fewer sightings during the period in question than the seventy years following — or preceding.

He dug deeper. Large sunspots can be seen without a telescope when the strong light is filtered either by clouds or by the Earth's atmosphere near sunset. Oriental skywatchers in particular scanned the solar surface for these dark patches. In 1933, an industrious Japanese astronomer cataloged these naked-eye sightings recorded in China, Japan, and Korea. Although these written observations averaged one a decade over fourteen centuries, not one was recorded between 1639 and 1720. The plotting of both the naked-eye sunspot sightings and auroral observations on graphs supported the journal statements.

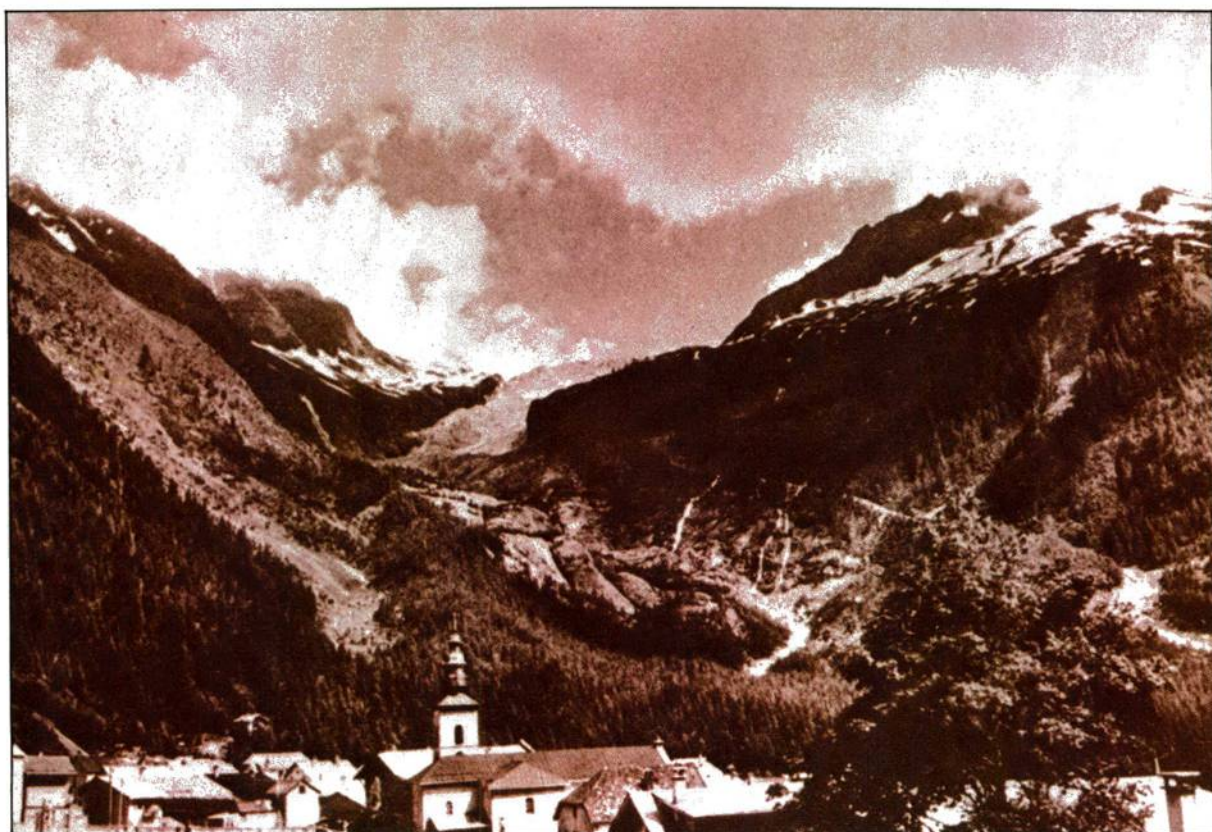
Eddy found himself intrigued by these facts and also by the human factor in this mystery. The astronomers of the period had contributed significantly to scientific advancement. Cassini discovered the first division in Saturn's rings; Roemer computed the velocity of light; Halley plotted the course of the famous comet that now bears his name. Astronomers of this period discovered five of Saturn's satellites and noted seven transits of Venus and Mercury across the face of the Sun. Not a single solar eclipse visible in Europe during this time escaped their careful attention. Compared to such achievements, the observation of sunspots is a simple task, not requiring a powerful and technically sophisticated telescope. Why would astronomers of such obvious ability fail? Eddy now questioned his original goal and began to refer to the period as the Maunder Minimum, in honor of the ignored



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This graph summarizes data collected from a variety of sources, each of which is either an index of solar activity or a measure of terrestrial climate. Definite maximum and minimum correlations in the data are marked by numbered circles. We are currently in the period known as the Modern Maximum (1), which was preceded by the Maunder Minimum (2), the Spörer Minimum (3), the Medieval Maximum (4), the Medieval Minimum (5), and the Roman Maximum (6). (Earlier Maxima and Minima have not been given specific names.) The top line (a) represents deviations in carbon-14 concentration from an arbitrary average. The second line (b) interprets the carbon-14 in terms of solar activity. The broken line T plots estimated annual temperatures in England over the last 1000 years. The curve W represents the winter-severity index for the Paris-London area (downward is colder). The step-curve G₁ depicts the advance and retreat of Alpine glaciers, and G₂ does the same for worldwide glacier fluctuations for a longer timespan. The background photo shows a drilling team extracting cores from ancient ice at an Antarctic site. Analysis of the datable ice layers helps to reveal the past history of solar activity. Photo courtesy of K. Kuivinen, Polar Ice Coring Office.



An old engraving compared to a modern photograph shows a definite retreat of this mountain glacier since the Little Ice Age of several centuries ago. Photos courtesy of the National Center for Atmospheric Research.

astronomer who first identified it.

One other clue lay buried in the old journals. Solar eclipses offer an opportunity to view the Sun's corona (upper atmosphere) while the Moon blocks the overpowering light from the solar disk. Eddy knew that the concentrated magnetic fields associated with sunspots produce the streamers that shoot out from the surface and give the corona its structure. In less active periods, the corona dims and loses its defined shape, so descriptions of the solar corona during an eclipse could provide an index of sunspot frequency. After studying the various descriptions and giving consideration to the purpose these men had for viewing eclipses, Eddy suspected that a structured corona was not a feature of the Sun during this whole period, a fact that indirectly supported an absence of sunspots.

Gathering New Evidence

As exciting as this accumulation of evidence seemed to Eddy, it was still just circumstantial, based on what was *not* observed. And as another astronomer pointed out, "Absence of evidence is not evidence of absence." Many explanations could be proffered for the records. Eddy needed irrefutable scientific proof if he were to succeed where Maunder had failed. He found this proof preserved in the chemical content of tree rings, a journal written by the Sun itself with an indelible ink called carbon-14.

The formation of this carbon isotope begins when cosmic rays bombard nitrogen atoms in the upper atmosphere. In active solar periods, the Sun's magnetic field is extended, somewhat shielding the Earth against these cosmic invaders. Thus more carbon-14 is produced during inactive solar periods than in active. Although there is a time delay, this isotope eventually works its way down to the lower atmosphere, entering the life cycle of trees as carbon dioxide through photosynthesis.

Chemical laboratories have performed carbon-14 analysis for years as a tool in archeological dating. In 1958, a Dutch scientist noted a marked increase in carbon-14 production in tree rings formed during the late 17th and early 18th centuries. Since the history of solar activity was little known at the time, the information was not associated with the dearth of sunspots during the same period. But combined with Eddy's other evidence, the testimony of this microscopic witness allowed him to rest his case. All the data — the old records, auroral observations, the naked-eye sunspot sightings, coronal structure during eclipse, and finally carbon-14 trapped in datable tree rings — all confirmed the prolonged sunspot minimum.

Eddy published his findings and introduced the world of solar astronomy to the concept of a variable Sun. Something in the solar dynamo could switch on and off. But why? Would it do so again? Was the Little Ice Age (as the cold period was called) actually caused by the Maunder Minimum, or was it just a tantalizing coincidence? In an explosion of research projects, the scientific community set out to answer the questions posed by John Eddy's data. Topping the list was the sunspot-climate relationship.

To probe this subject, investigators needed more extensive histories of both the Sun and climate. Long-lived trees (such as the bristle-cone pine) yielded several thousand years of data on solar behavior. Other periods of variation emerged from these studies, and they too coincided with temperature shifts. The Spörer Minimum between 1400 and 1510 marked the first temperature dip of the Little Ice Age. For the Norse colony in southwestern Greenland, the temperature shift spelled tragedy. Spring after spring the ice failed to thaw until finally, their supplies exhausted, the settlers perished. A period of high activity in

the 11th and 12th centuries, when the Norse colony was founded, corresponded to the period long known to climatologists as the Medieval Warm Epoch. In an article for the magazine *Natural History*, Eddy wrote: "At the time of each of the major changes in gross solar behavior in the last 5,000 years, the Earth's climate seems to have changed, offering perhaps the best clue yet to a Sun-climate connection."

Looking for More Evidence

But several thousand years is almost insignificant in the long life of our Sun. Other solar diaries offer much more ancient history.

Snowfall in polar regions freezes into ice datable from the annual layers. Nitrogen compounds locked in this ice may reflect auroral activity and thus indirectly solar activity. This technique has drawn criticism from some researchers who question the solar-related origin of the compounds. Recent analyses of ice cores collected from these areas, however, seem to correlate the changes in the nitrogen concentrations with periods of solar variation already established through the tree-ring studies (Maunder Minimum, Spörer Minimum, Medieval Maximum). This, of course, lends credibility to the process. Drilling crews at Greenland and Antarctic stations are presently removing more cores for further research.

An isotope of beryllium trapped in ocean sediment may provide the clearest record of solar activity. Like carbon-14, beryllium-10 is formed in the upper atmosphere by the impact of cosmic rays. When these rays are deflected by the solar magnetic field during periods of high solar activity, the production of beryllium-10 decreases. By measuring the variations in amounts of this isotope found in cores drilled from the sea floor, scientists hope to trace solar history back millions of years with a high degree of accuracy. This long-term perspective is needed before firm conclusions on the sunspot-climate relationship can be established.

But recovering solar history is only part of the task of understanding the Sun's variable behavior. The High Altitude Observatory (HAO) in Boulder, Colorado, where Eddy works, organized a section charged with researching all aspects of solar variability. Many of the resulting projects focus on the present, measuring and testing the Sun for signs of current change. The Sun's diameter, solar luminosity (total energy output), the solar corona, and the Sun's rate of rotation are all undergoing close scrutiny.

Computations made from old sunspot maps make the solar rotation question particularly interesting. The dated maps trace the daily progress of spots across the solar surface. Eddy and two of his associates at HAO, Peter Gilman and Dorothy Trotter, used this information to determine the solar rotation speed at different points in time. The resulting figures indicate an increased rate of rotation near the Sun's equator just before the onset of the Maunder Minimum. How did this change relate to the disappearance of sunspots? That question and many others are just beginning to be investigated.

Peter Gilman recently gave his own perspective on Eddy's research. "The Maunder Minimum had a big impact," he said. "It was the primary reason for going into solar variability. There must be 25 to 50 scientists who are doing something different now as a result of this work. More if you count the tree-ring people."

John Eddy solved the mystery of the missing sunspots, but it will be a long time before the file on solar variability can be marked "Case Closed."

Mary Martin DeLancy is a native of Louisiana now living in Boulder, Colorado. A graduate of the University of Colorado in Boulder, she is the author of a number of popular science articles and is currently working on her first novel set in the swamps of southern Louisiana.

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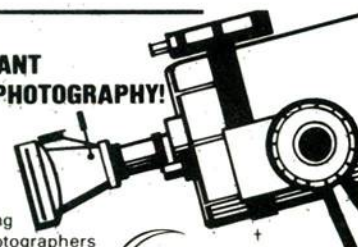
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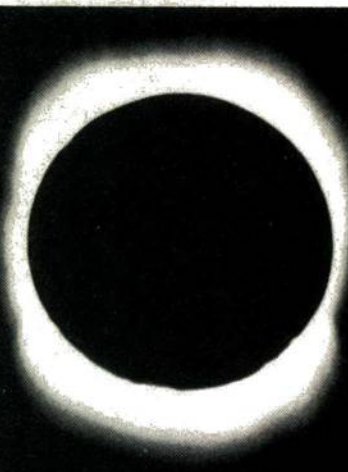
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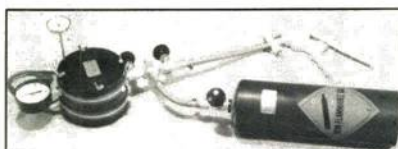
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ANNOUNCEMENT — Maine's statewide astronomy club is looking for new members in New Hampshire, Maine and New Brunswick. For details contact 45th Parallel Amateur Astronomers, RFD #1 Box 49D, Dexter, ME 04930.

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ANNOUNCEMENT — The Starblazers Fan Club is in a membership drive. We are fans of the T.V. show *Starblazers*. We have a newsletter that comes 4 times a year and costs \$1.10. Write Starblazers Fan Club, c/o Michael Pinto, 1622 Stevens Ave., Merrick, N.Y. 11566.

ANNOUNCEMENT — The Virginia Association of Astronomical Societies will hold a two-day convention May 30-31, 1981, at Old Dominion University, Hampton Blvd., Norfolk, VA in Chandler Hall. The guest speaker will be Walter E. Hamler. Many other speakers will also present papers. There will be a swap shop and competitions in astrophotography and telescope making. For further information contact Dr. Leonard W. Scarr, 2216 County Street, Portsmouth, VA 23704.

WANTED — Correspondence with anyone (over 21) interested in astronomy and astrophotography, plus science fiction. Contact Terry Rubin, 212 Dumont Pl., Philadelphia, PA 19116.

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close-up on monoceros/ canis minor

through
the
eyepiece

Thinking of holing up until Spring arrives for sure? Don't — the skies this month are offering you far more than just an invitation to frostbite: Jupiter and Saturn come into view by late evening and remain up for the rest of the night, Mercury puts in a brief appearance in the evening sky, and the Moon makes several interesting conjunctions with planets and stars.

Mercury

For the first 10 days or so of the month, Mercury will be visible low in the western sky after sunset. (See last month's *Through the Eyepiece* for a diagram showing its positions for January and February.)

At greatest eastern elongation on February 2nd, the little planet is relatively well placed for observation until about the 10th. Inferior conjunction comes on the 17th, and the following morning apparition in March won't be very good. Get busy now, or plan to wait until May for a good look at it.

On the evening of the 10th, Mercury will be 4° north of Mars, but locating them both will be very difficult in the glow of sunset.

Venus

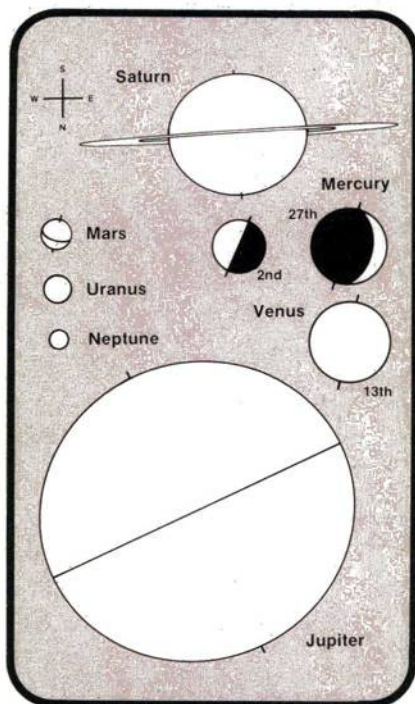
A few keen-eyed observers may be able to spot Venus low in the morning sky early in February. A very skinny Moon will be about a degree and a half north of it on the morning of the 3rd, but sometime thereafter Venus will vanish into the Sun's blaze. How late in the month can you follow it?

On the 22nd, Mercury will pass 6° north of Venus. Since this comes five days after Mercury's inferior

conjunction with the Sun and since both planets lie no more than 11° away from the Sun, you'll find them nearly impossible to spot.

Moon

Two days after it passes by Venus on the 3rd, the Moon, having swung through New into the evening sky, will glide past Mars. On the evening of the



5th, look for Mars about half a degree to the lower right of a very thin crescent Moon. About seven hours after it passes Mars, the Moon will overtake Mercury. Forty-five minutes after sundown that evening, you'll see Mercury about 7.5° high (in the west-southwest) with the Moon and Mars together, to the lower left.

On the afternoon of February 12th, the Moon will sweep through the

Hyades Cluster, occulting several stars as it goes, among them Aldebaran. The northwestern two-thirds of the country and just about all of Canada can see this daylight occultation; the southeastern third misses it.

During the night of February 17th-18th, the Moon passes about 2° south of M-44, the Beehive Cluster, in the heart of the zodiacal constellation Cancer. Binoculars or an RFT will be the best instrument to watch with.

The Moon overtakes Jupiter and Saturn, almost simultaneously, on the night of February 21-22. The conjunction with Jupiter comes just $8\frac{1}{2}$ minutes before that with Saturn; the separations are $3^\circ 7'$ (Jupiter) and $1^\circ 58'$ (Saturn).

The Moon passes Uranus on the 26th. At 6:37 UT, it lies $4^\circ 50'$ to the north of the planet. Neptune's turn comes two days later: on the 28th at 9:14 UT, the Moon sweeps by Neptune, lying $2^\circ 26'$ south.

Mars

Try to see the conjunction with the Moon and Mercury on the 5th.

Asteroids

1 Ceres (magnitude 7.1) is retrograding in northern Gemini. Look for it at the following positions:

10th: 7h 8m 36s, $+32^\circ 15.3'$

20th: 7h 4m 35s, $+32^\circ 23.9'$

Ceres transits around 9:30 p.m. local time on February 15th.

2 Pallas (8.9) is in eastern Cetus, its positions:

10th: 2h 33m 53s, $-17^\circ 0.4'$

20th: 2h 46m 55s, $-15^\circ 8.4'$

Pallas sets about 9:00 p.m. local time at mid-month.

3 Juno (10.7) lies near the Virgo/Libra border, its positions:

10th: 14h 29m 14s, $-7^\circ 2.4'$

20th: 14h 32m 3s, $-6^\circ 28.8'$

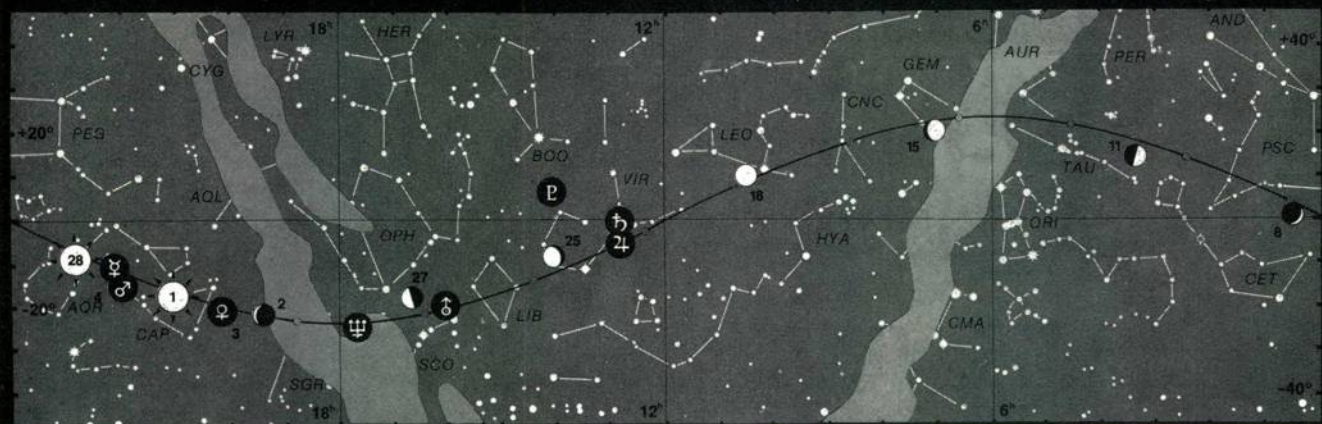
Juno rises around local midnight on February 15th.

4 Vesta (6.2) comes to opposition on the 21st and lies in central Leo, its positions:

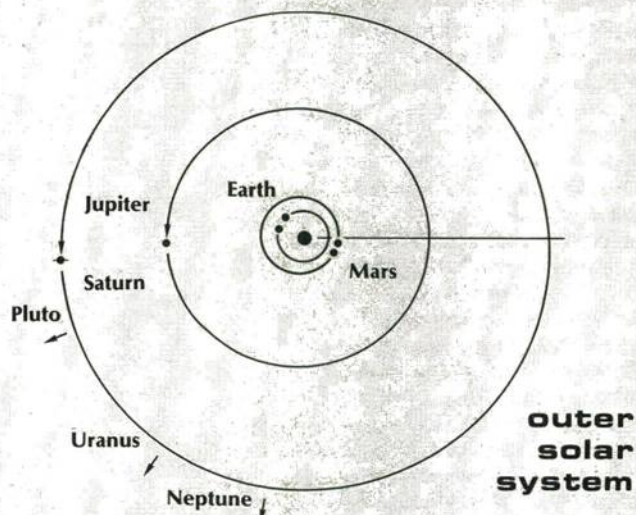
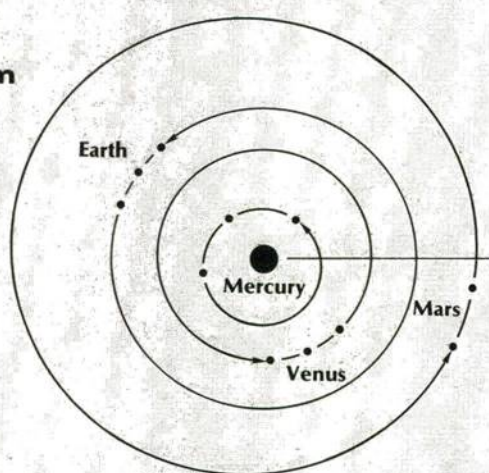
Glowing streamers of gas sprawl out from the brilliant core of M-42, the Orion Nebula; below lies NGC-1977. For this superb photo, Bill Iburg used an 8" Schmidt-Cassegrain telescope, a cold camera, 400 ASA film, and a 40-minute exposure at f/5 (via telecompressor). This is February's "Best Astro-Photo."

planetary data

february 1981



inner solar system



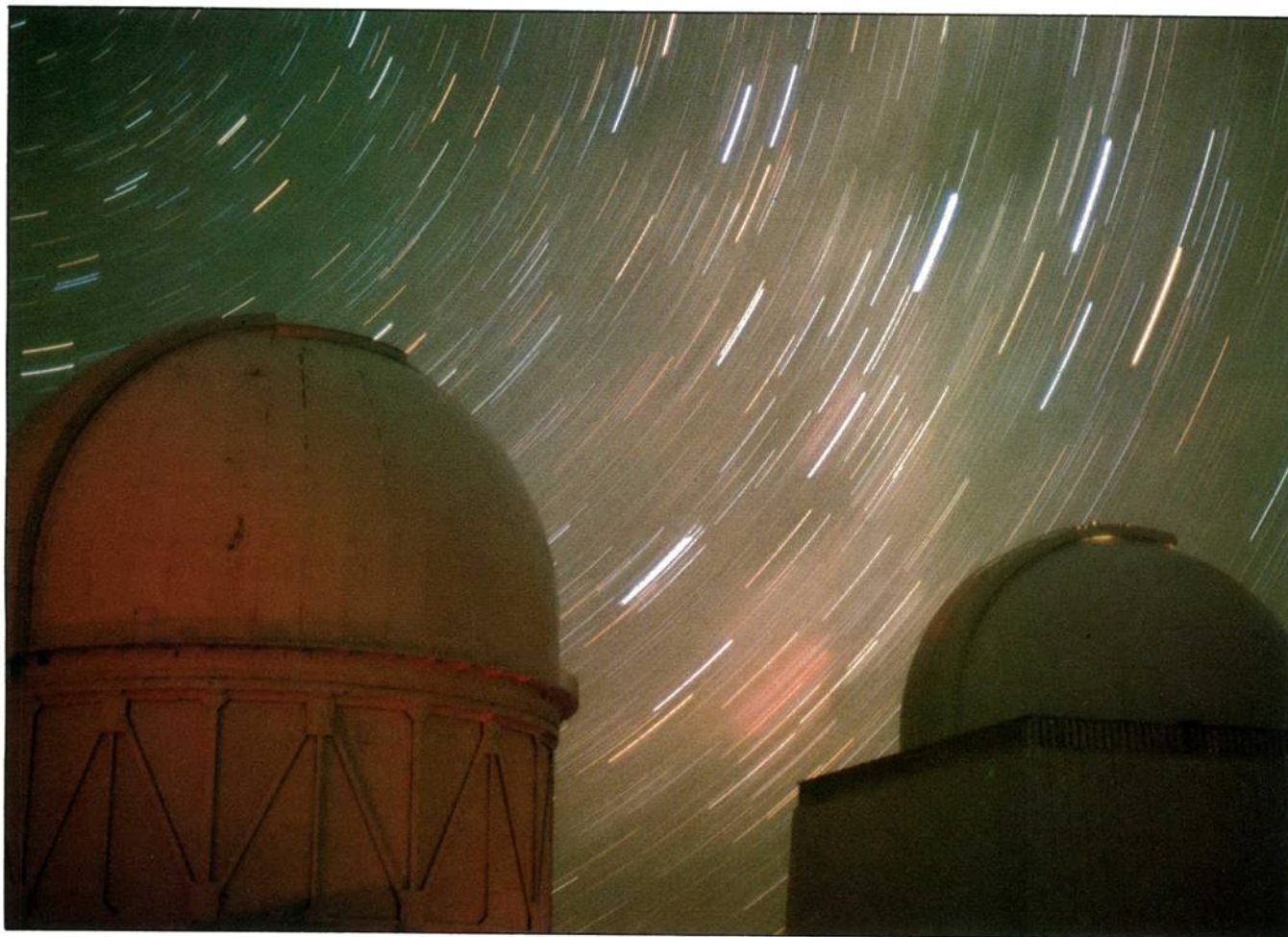
	Date	Mag.	Angular Size	% Illum.	Distance (AU)		Longitude:		R.A. (1981.2)	Dec
					Earth	Sun	Heliocentric	Ecliptic		
Sun	10	--	32.5'	--	0.98	--	--	321°10.6'	21 ^h 34.2 ^m	-14°26.7'
	20	--	32.4'	--	0.99	--	--	331°16.4'	22 13.2	-11°01.5'
Mercury ♿	10	+1.1	8.9"	17%	0.78	0.31	107°06.1'	334°17.4'	22 22.6	-7°25.8'
	20	+2.4	10.6"	3%	0.64	0.36	160°49.4'	325°27.6'	21 47.6	-9°26.1'
	28	+1.2	9.6"	20%	0.69	0.41	193°19.9'	319°49.5'	21 27.2	-12°31.9'
Venus ♀	10	-3.4	9.9"	97%	1.65	0.73	288°04.9'	306°46.0'	20 39.2	-19°14.2'
	28	-3.4	9.8"	99%	1.69	0.73	316°32.6'	329°15.9'	22 08.9	-12°46.3'
Mars ♂	15	+1.4	4.0"	100%	2.34	1.39	343°36.7'	335°56.5'	22 33.9	-10°06.1'
Jupiter ♃	15	-1.9	42.0"	100%	4.69	5.45	182°30.9'	189°14.9'	12 37.9	-2°27.2'
Saturn ♄	15	+0.8	18.9"	100%	8.80	9.54	185°05.5'	188°42.0'	12 37.6	-1°16.0'
Uranus ♅	15	5.9	3.6"	--	18.84	18.80	236°57.8'	239°23.9'	15 51.3	-19°55.3'
Neptune ♆	15	7.8	2.4"	--	30.73	30.28	262°46.4'	263°54.8'	17 35.9	-22°00.5'
Pluto ♇	15	14.0	--	--	29.56	30.07	202°34.1'	203°43.8'	13 53.7	6°59.0'

moon data

New Moon February 4 at 22:14
 First Quarter February 11 at 17:49
 Full Moon February 18 at 22:58
 Last Quarter February 27 at 01:14
 New Moon March 6 at 10:31
 First Quarter March 13 at 01:50
 Perigee: February 08 at 23h ... 368,205 km
 Apogee: February 24 at 17h ... 404,724 km

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times in *Through the Eyepiece* are UT unless noted otherwise. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on Jan. 2, then the time in EST would be 10 p.m. Jan. 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m. on March 4.



Sliding down in the southwestern sky, the Eta Carinae Nebula shows as a reddish, hazy patch between the domes, while higher up, near top center, spreads a dark area marking the Coal Sack Nebula. Terry Oswalt made this 22-minute shot with a 50 mm lens at f/1.4 on Ektachrome 400 at Cerro Tololo Observatory in Chile.

10th: 10h 45m 21s, +17° 14.3'

20th: 10h 36m 34s, +18° 40.2'

Vesta rises around 7:30 p.m. local time at mid-month.

(All asteroid positions are given in apparent coordinates.)

Jupiter & Saturn

Now approaching opposition (which comes on March 26th for Jupiter and 23 hours later for Saturn), both planets rise about 9 p.m. local time at mid-month and are well placed for observation most of the night.

The second of the three conjunctions between them this year (January 14th was the first) happens on February 19th at 7:08 UT, when Jupiter, moving retrograde (westward), passes 1° 9' south of Saturn.

Saturn lies very near Porrima, also known as Gamma (γ) Virginis, a 3rd magnitude double, being just 21' west and 10' south of the star on the 1st of February. During the month, your telescope and a low-power eyepiece will show Saturn slowly crawling

satellites of jupiter

8:00 ut

1	42130	.	.	.	.	16	43201	.	.	.	.
2	4301	.	.	.	.	17	43102	.	.	.	.
3	43102	.	.	.	.	18	43201	.	.	.	.
4	43201	.	.	.	.	19	42103	.	.	.	.
5	2103	.	.	.	.	20	40123	.	.	.	.
6	0243	.	.	.	.	21	4023	.	.	.	.
7	01234	.	.	.	.	22	21043	.	.	.	.
8	2104	.	.	.	.	23	32014	.	.	.	.
9	3014	.	.	.	.	24	31024	.	.	.	.
10	31024	.	.	.	.	25	3014	.	.	.	.
11	32014	.	.	.	.	26	12034	.	.	.	.
12	21034	.	.	.	.	27	02134	.	.	.	.
13	01423	.	.	.	.	28	10234	.	.	.	.
14	40123	.	.	.	.						
15	42103	.	.	.	.						

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)



As comet P/Stephan-Oterma passed M-1, the Crab Nebula, on December 5th, Lee Coombs snapped its photo. He used his 10" Newtonian scope at f/5 (prime focus), 103a-O film, and a 10-minute exposure.

westward away from Gamma.

With both planets near their maximum apparent size, right now is about the best time to be looking for details in their cloud belts — even on quiescent Saturn. Of course, Jupiter's mighty storms have been observed (and enjoyed) for a long time, but Saturn, too, has outbreaks of atmospheric violence. Often taking the form of white spots near the equatorial belts, saturnian storms lack the variety of form and color you see on Jupiter. Nevertheless, when found they appeal greatly — maybe just because they're unusual and subtle!

Uranus

To find Uranus (a morning object, rising about 2 a.m. local time on the 15th), first locate Beta (β) Scorpii, a 2.9 magnitude double star. Then, using a low to moderate-power eyepiece, sweep your scope west 3° to $3\frac{1}{2}^\circ$. Sixth magnitude Uranus, identifiable by its 3.6" disk, will slide through your field of view.

Neptune

Also in the morning sky (rising about 3:30 a.m. local time at mid-month), Neptune lies 2° north and 1° to $1\frac{1}{2}^\circ$ east of 51 Ophiuchi, a 4.9 magnitude star. Neptune is at magnitude 7.8 and has a 2.4" disk.

observers' reports

From Gus Johnson: On July 14, 1980 I made a rather unusual observation of telescopic meteors. I was observing the field of RW Sagittarii with my 8-inch reflector at 58x and 116x. Roughly a minute of time apart, two meteors crossed my field in the same direction. A minute or so later, a third one came, but at a small angle to the first two. The general direction suggested that they might be Capricornids.

From John Brooks, of Santa Barbara, California: I was interested to read in the November issue about observing NGC-7331 and Stephan's Quintet in Pegasus.

My friend Dick Willingham and I were observing early in September on a night which I considered to have good, but not exceptional, transparency. I had my C-8 set up at my home at Painted Cave in the mountains above Santa Barbara.

I turned the telescope to NGC-7331 since Dick hadn't seen it before — and I had no trouble locating it. Then, on impulse, I moved the telescope half a degree SSW to where I had read that Stephan's Quintet was located. I saw a faint amorphous blob which I couldn't resolve into individual objects.

Without telling Dick what I thought I had in the field, I asked him what he saw. He said he saw four objects. We checked one another by moving the objects to the edge of the field, but not telling where, and asking the other to re-center them. We did so without difficulty.

I then looked up NGC-7331 in my copy of the *Hubble Atlas of Galaxies* and noted that there are two other fairly bright-looking galaxies nearby. Pointing the telescope to their locations, we were able to see NGC-7335 but not 7336.

The next day I checked Stephan's Quintet in Burnham's *Handbook*. Imagine my surprise when I found the magnitudes of the members of this group to range from 13.7 to 15.3...too faint to be seen in an 8-inch telescope!

The lunar craters Ptolemaeus, Alphonsus, and Arzachel stand out ruggedly in Brian Tkachyk's photo. He used an 8" Schmidt-Cassegrain, eyepiece projection, and a 4-second exposure on 64 ASA film.

Referring to my NGC catalog, I found the magnitude of 7335 to be 14.5 — also too faint to be seen.

I suppose the moral here is: never assume an object is too faint to be seen with your telescope — for psychological blindness may prevent your seeing it!

close-up on monoceros/canis minor

This month we look at the unicorn and the dog — actually the lesser dog, Canis Minor, and his neighbor Monoceros just to the south. Except for Procyon, this is a dim region lacking bright beacons, but one which is surprisingly "rich in groups and clusters," as Webb puts it.

There is indeed much here to delight both binocular and telescopic observers. This region has even been praised in verse by the classic observer Admiral Smyth:

*Let Procyon join with Betelgeuse,
And pass a line afar,
To reach the point where Sirius
glows —
The most conspicuous star;
Then will the eye delighted view
A figure fine and vast,
Its span is equilateral,
Triangular its cast.*

A good title for this region might well be "Smyth's Triangle," since the area enclosed by Betelgeuse, Procyon, and Sirius, through which the winter Milky Way flows, does in fact include most of the region's objects of interest.

A good place to begin your exploration of Smyth's Triangle is with **Epsilon (ϵ) Monocerotis**, just south of a point one-third of the way along the line from Betelgeuse to Procyon. This delightful blue and gold double star (actually a triple, with a dim 13th magnitude component 94" distant) is set in a magnificent, rich field, so be sure to use a low-power, wide-field eyepiece. The two components are separated in distance by an easy 13 seconds of arc (position angle 27°), and in brightness by two magnitudes. Most observers find the brighter A component a brilliant blue-white, its color brought out by contrast with the dimmer golden-yellow companion.

Now swing your telescope just five minutes of right ascension east from Epsilon and then nearly 12° straight south to **Beta (β) Monocerotis**, and

minima of algol

(times of middle of primary eclipse)

Date	Time (UT)
Feb. 5	7:44
8	4:33
11	1:22
13	22:12
28	6:18





Recognized since 1916 as being irregularly variable both in extent and brightness, NGC-2261 (now known as Hubble's Variable Nebula) has an actual length of about 7 light-years and lies about 2600 light-years distant (see text below). The photographer, Richard Hill, sent no technical data.

behold one of the finest triple stars in the sky. Visible to the naked eye a little over a third of the way from Sirius to Betelgeuse, Beta is sometimes labeled 11 Monocerotis in atlases and observing lists, and those familiar with Sir William Herschel's estimation of Beta as "one of the most beautiful sights in the heavens" may refer to it as "Herschel's Wonder Star."

However it is termed, this system consists of 4.7, 5.2, and 5.6 magnitude yellowish suns in a slender triangle whose greatest extent is 10 seconds of arc. All three components have the same spectral type — B3 — which is why most observers see them all identical in color, though a few do report subtle differences. What do you think?

The complex object listed in our table as NGC-2237/9 and NGC-2244 is far better known as the **Rosette Nebula**. Located about two degrees directly east of Epsilon Monocerotis, it

can be picked up by sweeping in right ascension with low power from that star. Strikingly beautiful in color photographs, the Rosette Nebula itself — NGC-2237/9 — is difficult to see visually because of its large size and low surface brightness. Measuring twice the apparent size of the full moon, low power and a very wide field are necessary to glimpse its pale glow. A four-inch (or larger) richest field telescope is ideal for attempting to observe it.

Much easier is the associated open cluster NGC-2244 — a splendid grouping of bright and faint stars surrounding the giant yellow sixth magnitude sun 12 Monocerotis. NGC-2244 is loose and irregular, containing perhaps two dozen stars in an area 40 minutes across, and lies near the central "hole" of the Rosette Nebula.

NGC-2261 is Hubble's famous **Variable Nebula**. Found almost exactly halfway between S and 13 Monocerotis, this tiny (2' diameter) smudge of light varies both in brightness and apparent size. Usually around tenth magnitude, it is not an easy object to observe, but those with at least 10 inches of aperture may be able to monitor its changes, sometimes perceptible over a period of days. The illuminating star, **R Monocerotis**, is

itself an irregular variable which attains a peak magnitude of about 9.5. It is obviously this star which is responsible for the changes in the appearance of the nebula, not actual motion in the nebula itself.

NGC-2264, like the Rosette Nebula, consists of a cluster associated with a nebula. But here there is still another element in the action: the presence of the double/variable star **S Monocerotis**. This latter object consists of a 4.7 magnitude primary which is an irregular pulsating sun together with an eighth magnitude companion only three seconds of arc distant. (There is also a dim 11th magnitude component 17" away.) The observed magnitude range of the variable component is only about half a magnitude. The cluster, which includes S Mon, is a modest group of about 20 stars scattered over a field the size of the full moon.

The surrounding diffuse nebula incorporates the famous **Cone Nebula**, a dark obscuring shaft at the southern portion of the nebulosity. Like the Rosette, this region is much more impressive in photographs than it is visually. With a large size of 60' by 30', it is a difficult object, but one well worth the search in six-inch and larger instruments.

Two more open clusters in Monoceros command our attention. Similar in size and total brightness, it is interesting to compare the appearance of the two. NGC-2301 is a grouping of about 60 stars, while **M-50**, located farther to the south about one-third of the way along a line from Sirius to Procyon, is a richer cluster of around 100 stars. The total integrated magnitude of NGC-2301 turns out to be greater than that of M-50 because the former includes many more relatively bright stars than the richer but dimmer population of M-50.

Turning to the upper left apex of Smyth's Triangle, we find the first magnitude star **Alpha (α) Canis Minoris** — much better known as **Procyon**. About eleven light-years distant, Procyon is one of our nearest stellar neighbors. But its chief claim to fame is the white dwarf companion, the second closest (after Sirius B) of all white dwarfs. Eleventh magnitude and only 4 arc-seconds away from the brilliant primary, Procyon B is even more difficult to spot than Sirius B. Still, those who like challenge (and who have been able to see the companion to Sirius) can look for Procyon B in position angle 330°.

The dim region of Smyth's Triangle thus turns out to have a remarkable variety of unusual objects, some of which have no counterpart anywhere else in the sky. There is a lesson for us here: delightful surprises are often found where you least expect them!

**NGC-2237/9,
NGC-2244**



David Healy

Beta Monocerotis

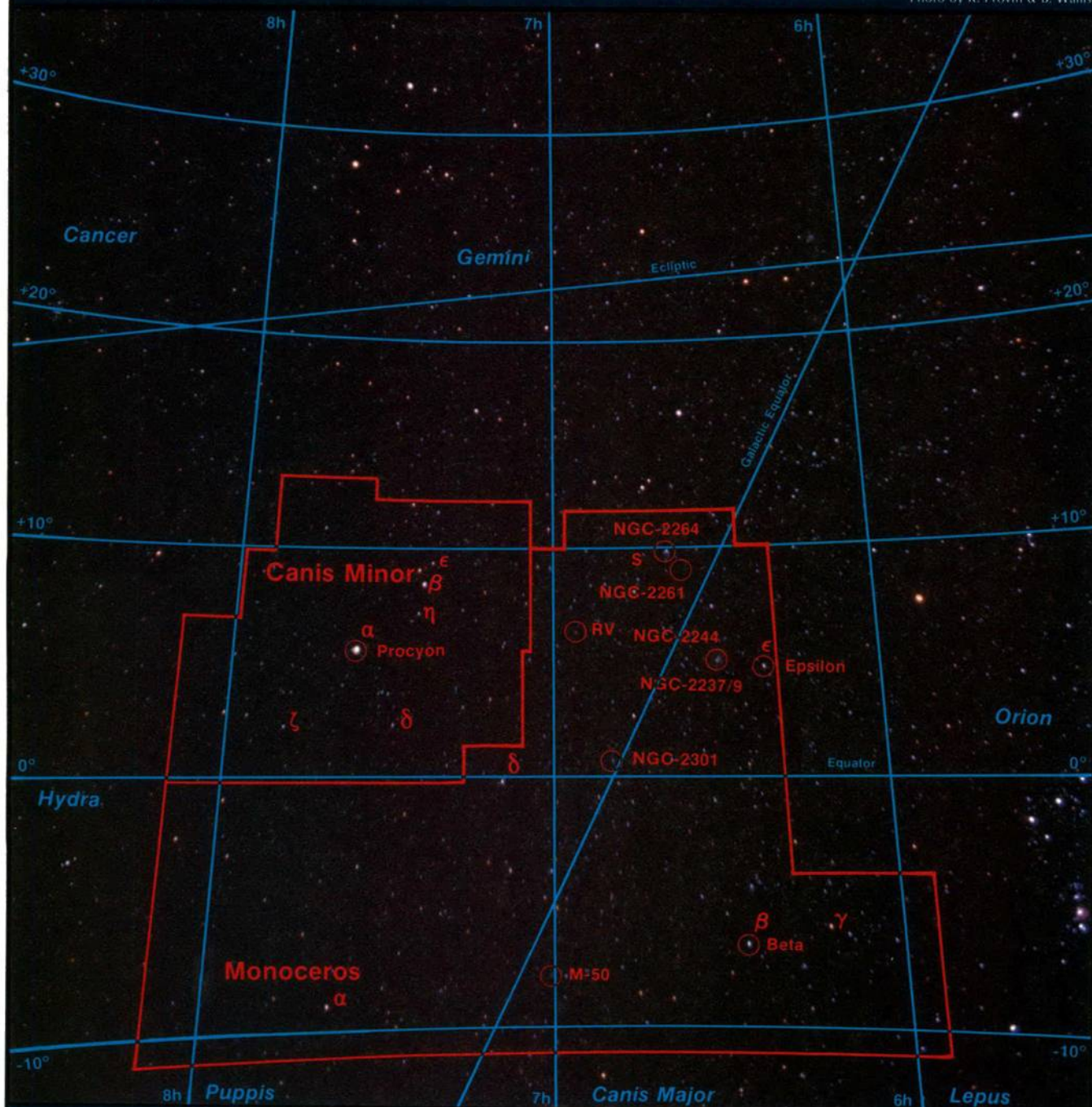


J. Mullaney

Map by
Dewey Schwartzburg

monoceros/canis minor

Photo by R. Provin & B. Wallis



Object	Type	Mag.	Size/Sep. Per.	R.A. (1950) Dec.	R.A. (1981) Dec.	
Epsilon (ε) Mon	★ ²	4.5, 6.5	13"	06 21 +04°37'	06 23 +04°53'	★ Star
Beta (β) Mon	★ ³	4.7, 5.2, 5.6	7", 3"	06 26 -07°00'	06 28 -07°01'	★ ² Double Star
NGC-2244	○	6.2	40'	06 30 +04°54'	06 32 +04°53'	★ ³ Triple Star
NGC-2237-9	□	—	64' x 61'	06 30 +04°40'	06 32 +04°39'	★ Regular Variable
NGC-2261	□	Var.	2' (Var)	06 36 +08°46'	06 38 +08°44'	★ Irregular Variable
NGC-2264	○/□	4.7	30' / 60' x 30'	06 38 +09°57'	06 40 +09°55'	★ Eclipsing Variable
S Mon	★ ²	4.7, 8.0	3"	06 38 +09°57'	06 40 +09°55'	○ Open Cluster
NGC-2301	○	5.8	15'	06 49 +00°31'	06 51 +00°29'	● Globular Cluster
RV Mon	★	6.3-8.3	132d	06 56 +06°14'	06 58 +06°11'	■ Planetary Nebula
M-50	○	6.9	16'	07 00 -08°16'	07 01 -08°19'	□ Bright Diffuse Nebula
Alpha (α) CMn	★ ²	0.3, 10.8	4"	07 37 +05°21'	07 38 +05°17'	§0 Elliptical Galaxy
						§S Spiral Galaxy
						§f Barred Spiral Galaxy
						§# Peculiar/Irregular Galaxy

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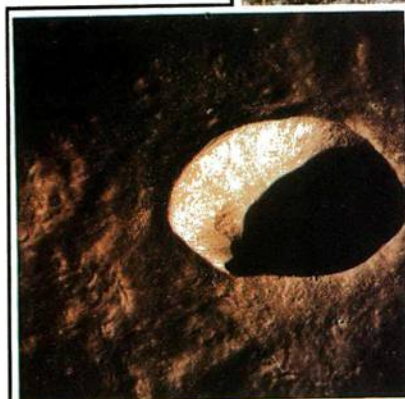
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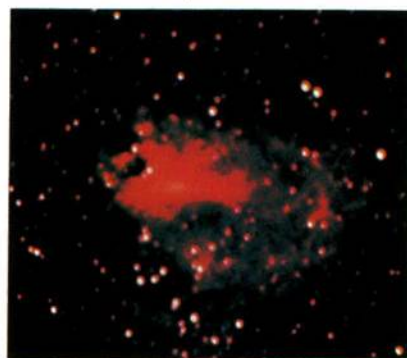
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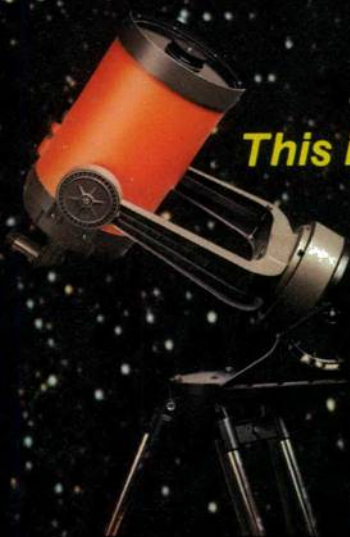
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